Australian Government

Australian Fisheries Management Authority

Status of the Northern Prawn Fishery Tiger Prawn Fishery at the end of 2023 with estimated TAEs for 2024 and 2025

Final Report

AFMA Project No. 2020/0803

October 2024

This document can be cited as:

Denham Parker, Roy Deng, Trevor Hutton, Margaret Miller, Tom Kompas, Amelia Desbiens, Sean Pascoe, Éva Plagányi and Andre Punt. 2024. Status of the Northern Prawn Fishery Tiger Prawn Fishery at the end of 2023 with estimated TAEs for 2024 and 2025. Report to the Australian Fisheries Management Authority, October 2024. CSIRO. Brisbane. 87 p.

AFMA Project No. 2020/0803: Northern Prawn Fishery Assessments 2022-2024.

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Version	Updates	Approver
Version 1	Draft Final Report	AFMA
Version 2	Final Report	AFMA

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Acronyms

- **NPF:** Northern Prawn Fishery
- **NPRAG:** Northern Prawn Fishery Resource Assessment Group
- **Steepness** is a parameter obtained from the stock-recruitment relationship and is the proportion of recruitment from an unfished population obtained when the spawning stock biomass is at 20% of its unfished level.
- **TAE** is the Total Allowable Effort
- **C_{2023}** is the observed catch in 2023
- **MAV** is the Moving Average
- **MSY** is the Maximum Sustainable Yield
- **MEY** is the Maximum Economic Yield
- **S_{MEY}/S_{MSY} (%)** is the spawning stock size at Maximum Economic Yield relative to the spawning stock size at Maximum Sustainable Yield as a percentage.
- **S_{2023}/S_{MSY} (%)** is the spawning stock size in 2023 relative to the spawning stock size at Maximum Sustainable Yield as a percentage.
- **S_{2023}/S_{MEY} (%)** is the spawning stock size in 2023 relative to the spawning stock size at Maximum Economic Yield as a percentage.
- **5-year mav($S_{2019\text{-}2023}/S_{MSY}$) (%)** is the 5-year moving average of the spawning stock size between 2019 and 2023 inclusive relative to the spawning stock size at Maximum Sustainable Yield.
- **S_{2030}/S_{MEY} (%)** is the projected spawning stock size in 2030 relative to the spawning stock size relative to Maximum Economic Yield as a percentage.
- **E_{2023}** is the observed effort in 2023.
- **E_{2024}** is the model estimated effort for 2024.
- **E_{2025}** is the model estimated effort for 2025.
- **E_{MSY}** is the effort at the Maximum Sustainable Yield.
- **E_{MEY}** is the effort at the Maximum Economic Yield.
- **E_{MEY}/E_{MSY}** is the effort at the Maximum Economic Yield relative to the effort at the Maximum Sustainable Yield.
- **E_{2023}/E_{MSY} (%)** is the observed effort in 2023 relative to the effort at the Maximum Sustainable Yield as a percentage.

- **E_{2023}/E_{MEY} (%)** is the observed effort in 2023 relative to the effort at the Maximum Economic Yield as a percentage.
- **Standardised E_{2023}/E_{MSY} (%)** is the standardised effort in 2023 relative to the effort at the Maximum Sustainable Yield as a percentage.
- **Standardised E_{2023}/E_{MEY} (%)** is the standardised effort in 2023 relative to the effort at the Maximum Economic Yield as a percentage.
- **NA** indicates the value is not applicable or not available.

For model combinations (e.g., **SSB**, **DDD**): **D** – refers to the delay difference model, **S** – for the size structured model and **B** – for the Bayesian biomass production model.

Note: for many of these indicators the 2024 equivalent is provided.

Executive Summary

The objective of the Commonwealth Fisheries Harvest Strategy Policy is the sustainable and profitable utilisation of Australia's Commonwealth fisheries in perpetuity, through the implementation of harvest strategies that maintain key commercial stocks at ecologically sustainable levels and within this context, maximise the economic returns to the Australian community (Dichmont et al. 2012b).

As applied to the Northern Prawn Fishery (NPF) Tiger Prawn Fishery, the operational objective of this policy is to attain long term Maximum Economic Yield (MEY). This is implemented by maximising the net present value of the flow of economic profits in the fishery over a 40-year period, in this case up to 2063. The dynamic optimisation of a seven-year path to the long-term MEY is calculated as the effort level and associated catch in each year, over a seven-year projection period that leads to a long-term sustainable yield that maximises economic profits over time.

In this assessment, a multispecies, weekly sex- and size-structured population model for Tiger Prawns is combined with a Bayesian biomass production model for Blue Endeavour Prawns, and an economic model that calculates profit (the "Base case" model). This system requires predictions about future effort levels, and changes over time in costs and prices (Punt et al. 2011). Several alternative scenarios are presented to provide sensitivity analyses for these assessments.

Two groups of stock assessment models were applied: a) the Base Case, comprised of size-structured models (for two Tiger Prawn species), as well as a Bayesian biomass dynamic model (for Blue Endeavour Prawns); and b) Deriso models for each of the three species (Dichmont et al. 2003). The latter Bayesian and Deriso models do not use the length frequency information.

Punt et al. (2011) provides a comprehensive overview of the combined model used as the Base Case, but in summary, the Base Case assessments have two components: (1) the stock assessment of the two Tiger Prawns plus Blue Endeavour Prawns, and (2) the bio-economic assessment (Dichmont et al. 2008, Punt et al. 2011, Deng et al. 2015). A Blue Endeavour Prawn and Red Endeavour Prawn assessment (the latter is incorporated as a four species model sensitivity test) were undertaken with the improved Bayesian biomass dynamic model (Zhou et al. 2023). Prior to the development of the most recent Endeavour Prawn model, a delay difference model (Dichmont et al. 2003) and the hierarchical

Bayesian biomass dynamic model (Zhou et al. 2009) were applied to the Endeavour Prawns. Sub-optimally, the delay difference model required several input parameters that were poorly estimated, particularly for Red Endeavour Prawns, and the hierarchical Bayesian biomass dynamic model used the Tiger Prawn fleet fishing power which would over-estimate the impact of fishing on these species.

In the bio-economic model, Blue Endeavour Prawns (or in the four species sensitivity test, both Blue Endeavour Prawns and Red Endeavour Prawns) are treated as an economic byproduct i.e., effort is not directed at the species, but catches provide revenue and attract costs associated with the amount caught (such as freight and packaging). This assessment continues to include the additional fourth species (Red Endeavour Prawn) as a sensitivity test.

Various model improvements were included in the previous assessments (Deng et al, 2022; Hutton et al, 2018; Buckworth et al. 2015) based on a retrospective study of model performance (Deng et al. 2015). In addition to the mandatory data updates, the 2024 assessment incorporated several revisions. Some of these revisions were implemented as a result of outcomes from the NPF Tiger Prawn Fishery Adaptation Strategy Workshop Report in February 2023 (Jarrett et al., 2023). The revisions/changes/data updates for the 2024 Tiger Prawn assessment include:

- Updated logbook catch and effort data for 2022 and 2023 are added in the catch and effort time series.
- Updated monitoring survey data are added, including abundance indices and length frequency data. The additional survey indices are from 2023, 2024 recruitment surveys and 2022 spawning survey. The length frequency data are from 2022, 2023 recruitment surveys and 2022 spawning survey.
- Updated economic data for calendar year 2023 is incorporated, and in contrast to previous assessments the fuel cost projection is fixed at a constant fuel cost based on the April 2024 fuel price provided by NPFI. Prawn price projection is also assumed as constant (fixed) at the 2023 observed values.
- A new species splitting model (Parker et al., 2023) is applied to the entire catch and effort time series (1970-2023) to build species-specific catch and effort data. These provide fundamental input data for the Tiger Prawn and the Endeavour Prawn stock assessment models.

- The bio-economic model Minimum Effort Threshold (MET) was revised such that a combined MET value is now applied, as opposed to two separated fleet (species) MET values in previous assessments.
- The bio-economic MET was revised to be fixed at 4004 boat days, in total.
- Recently developed Blue and Red Endeavour Prawn stock assessment models (Zhou et al., 2023) were applied and integrated into the bio-economic model for the multi-species assessments in terms of MSY and MEY.
- An interannual percentage change penalty was applied to effort projections in the bio-economic model to avoid MEY projection pathways that have extremely high effort fluctuations between years. This penalty was implemented at 100% interannual effort change level, with sensitivity tests produced for 50% and 200% levels.
- Several sensitivity tests were run to ascertain the influence of various input data and model assumptions on the assessment results. These sensitivities included variations to the amount of effort change permitted between years, variations to the MET, alternative fishing power levels, model structures, predicted fishing patterns, and the inclusion of Red Endeavour Prawns in the bio-economic model.

The ‘revisions’ were undertaken as follows. A “species-split” model, to allocate logbook catches and effort by species of Tiger and Endeavour Prawns, was updated from its previous version (Venables et al. 2006) to its latest version (Parker et al., 2023) and was applied to the updated fishery catch and effort data. Two updated (April 2024) fishing power models were applied as separate scenarios – the “low” model (used in the Base Case) and the “mid-high” model as a sensitivity (Nov 2009 and May 2010 Northern Prawn Fishery Resource Assessment Group (NPRAG), see Bishop et al. 2010 for description of method).

For the Base Case assessment, we used the NPRAG 2014-specified season (average of the last two years) as the fishing effort pattern (as agreed by NPRAG in March 2014 and November 2015) for the forward projections.

Differences in the results from previous assessments can mostly be attributed to: a) new implemented species catch and effort splitting model; b the updated fishing power series; c) the addition of the 2022 spawning survey, the 2023 and 2024 recruitment survey abundance indices and length frequency data; d) updated fishery catch and effort logbook data up to 2023; e) an updated fishing effort pattern; f) updated current and forecasted economic information; g) implementation of new MET as combined value for the two Tiger Prawn fleets. These changes together have influenced the stock status estimates for the various species and the stock-recruitment relationship, as well as the Maximum Sustainable Yield (MSY) - and Maximum Economic Yield (MEY)-related outputs. The MEY estimate drives the Total Allowable Effort recommendation calculated by applying the harvest strategy.

This assessment produces a Total Allowable Effort (TAE) recommendation for the following two consecutive years, for the NPRAG to consider.

Grooved Tiger Prawns (Figure 1)

The Base Case stock status for Grooved Tiger Prawn is S_{2023}/S_{MSY} = 1.08 (Table 1), and the moving five-year average stock status $S_{2019\text{-}2023}/S_{MSY}$ = 1.07. Across all the scenarios tested, Grooved Tiger Prawn stock status (S_{2023}/S_{MSY}) ranged between 0.91 - 1.47 and the moving five-year average ($S_{2019\text{-}2023}/S_{MSY}$) range was 0.91 - 1.45 (Figure A2). Thus, the 2024 stock status for Grooved Tiger Prawn is above the limit reference point of $0.5S_{MSY}$. Effort was well below that at E_{MSY}, with E_{2023}/E_{MSY} estimates ranging between 0.24 – 0.66. Grooved Tiger Prawns are therefore considered not overfished, and overfishing is not occurring.

Brown Tiger Prawns (Figure 2)

The Base Case stock status for Brown Tiger Prawn is S_{2023}/S_{MSY} = 0.81 (Table 1), and the moving five-year average stock status $S_{2019\text{-}2023}/S_{MSY}$ = 0.87. The stock status (S_{2023}/S_{MSY}) ranged between 0.70 - 0.90 in all scenarios tested (Figure A3). Furthermore, the moving five-year average ($S_{2019\text{-}2023}/S_{MSY}$) ranged between 0.76 – 0.96, and thus above the limit reference point of 0.5 S_{MSY}. Effort was well below that at E_{MSY}, with E_{2023}/E_{MSY} estimates ranging from 0.32 to 0.57. Therefore, Brown Tiger Prawn are considered not to be overfished nor is overfishing occurring.

Blue Endeavour Prawns (Figure 3)

The Base Case stock status for Blue Endeavour Prawn is S_{2023}/S_{MSY} = 1.17 (Table 1), and the moving five-year average $S_{2019\text{-}2023}/S_{MSY}$ = 0.95. In all the sensitivity scenarios tested, the Blue Endeavour Prawn stock status (S_{2023}/S_{MSY}) ranged from 0.77 – 1.33, while the moving five-year average ($S_{2019\text{-}2023}/S_{MSY}$) ranged from 0.82 – 1.07 (Figure A4). Blue Endeavour Prawn is, therefore, not considered to be overfished according to the limit reference point of 0.5 S_{MSY} based on a five-year moving average.

Red Endeavour Prawns (Figure 4)

In the four species sensitivity test, the Red Endeavour stock status was S_{2023}/S_{MSY} = 1.08 (Figure A5), while the five-year moving average $S_{2019\text{-}2023}/S_{MSY}$ = 1.00. Red Endeavour Prawn is, therefore, not considered to be overfished according to the limit reference point of 0.5 S_{MSY} based on a five-year moving average or the 2023 biomass estimate.

Bio-economic assessment (Table 1, Figure 5 and Figure 6)

Relative to Maximum Economic Yield (MEY), the Base Case Grooved Tiger Prawn stock status was S_{2023}/S_{MEY} = 0.72. The S_{2023}/S_{MEY} estimates ranged between 0.68 - 0.76 in all the scenarios tested. Similarly, the Brown Tiger Prawn Base Case estimate was S_{2023}/S_{MEY} = 0.57 and ranged between 0.51 - 0.62 in all scenarios. For Blue Endeavour Prawns the Base Case estimate was S_{2023}/S_{MEY} = 1.18 and ranged between 0.56 - 1.18 in all scenarios tested. In the four species scenario, the estimate for Red Endeavour Prawns was S_{2023}/S_{MEY} = 1.22.

Model projections indicate that the Grooved Tiger Prawn stocks will achieve the current target reference point, S_{MEY}, by 2031. However, Brown Tiger Prawn’s current stock status is lower than that of Grooved Tiger Prawn and will, therefore, require a longer period to achieve S_{MEY} (Figure 5).

In 2023, targeted effort relative to MSY on Grooved Tiger Prawns was E_{2023}/E_{MSY} = 0.43 and Brown Tiger Prawns was marginally higher, E_{2023}/E_{MSY} = 0.52; both values suggest that the current effort is substantially lower than that required to achieve maximum sustainable yield, i.e., the ratio as 1. As Blue Endeavour Prawns and Red Endeavour Prawns are treated as a byproduct (i.e., captured when effort is targeted at Tiger Prawns), the effort indicator is not applicable for these two species. The 2024 catch projections indicate an expected decrease in Grooved Tiger Prawn catches compared to 2023, from 921 tons to 675 tons. In contrast, projected catches for Brown Tiger Prawns are expected to increase marginally in 2024 compared to 2023, from 321 tons to 361 tons. These catch projections are dependent on the associated species-specific effort allocation (Table 2).

The NPF Tiger Prawn fishery is projected to be run at a financial deficit for the whole projected period given the current estimates of target species’ stock status and, more importantly, the economic data and assumptions on future costs and prawn prices (Table 1). The major economic drivers are the significant increase in the fuel cost, as well as the repair and maintenance costs (Table 8).

Notably, the 2023 Base Case S_{MEY}/S_{MSY} values for Grooved and Brown Tiger Prawns are 1.50 and 1.43, respectively, which are substantially higher than the conventionally accepted proxy of S_{MEY}/S_{MSY} = 1.2. This suggests that a high available prawn biomass is required to maximise economic yield. Simply put, given the current economic climate (i.e., the relatively high cost of fishing) high catch rates are required maximise economic yield. However, the elevated catch rates required to reach MEY are only possible when prawn biomass is high; higher than current stock status. Given the assumption of constant price and cost projections, substantial growth in the biomass (S_y/S_{MSY}) will be required for both species (see Figure 1 and Figure 2) to shift the current S_{2023}/S_{MEY} estimates of 0.72 and 0.57 for Grooved and Brown Tiger Prawn, respectively, toward the target reference point of S_{2023}/S_{MEY} = 1 by 2030. For Blue Endeavour Prawns (Base Case) and Red Endeavour Prawns (four species sensitivity test), the S_{MEY}/S_{MSY} ratios are 0.99 and 0.88, respectively. Importantly, the costs for Blue Endeavour Prawns and Red Endeavour Prawns, caught as a byproduct, are limited to those associated with catch (e.g., packaging and freight) but not effort (e.g., fuel).

Total allowable effort (Table 2) **– that is the model estimated TAEs**

The Tiger Prawn Base Case results indicate that the 2024 fishing effort levels required to achieve MEY are 2645 boat days for Grooved Tiger Prawns and 1368 boat days for Brown Tiger Prawns; a total of 4013 boat days (Table 2). The optimal 2024 fishing effort estimates derived from the various sensitivity tests ranged between 1536 - 4430 boat days in total, noting that the lowest value resulted from the scenario where no minimum effort threshold (MET) was applied – the Base Case TAE estimates are currently being constrained by the MET. The 2025 projected total fishing effort remains 4013 boat days, however effort targeted at Grooved Tiger Prawns increases to 3036 boat days, while a reciprocal decrease is observed for Brown Tiger Prawns to 977 boat days.

Figure 1. Status of the stock and effort relative to reference points for Grooved Tiger Prawns, for the Base Case.

Top-left) Spawning stock size (S_Y) relative to the spawning stock size at Maximum Sustainable Yield (S_{MSY}), Top-right) spawning stock size relative to the spawning stock size at Maximum Economic Yield (S_{MEY}), Bottom-left) standardised effort (E_Y) relative to the effort at Maximum Sustainable Yield (E_{MSY}), and Bottom-right) standardised effort relative to the effort at Maximum Economic Yield (E_{MEY}).

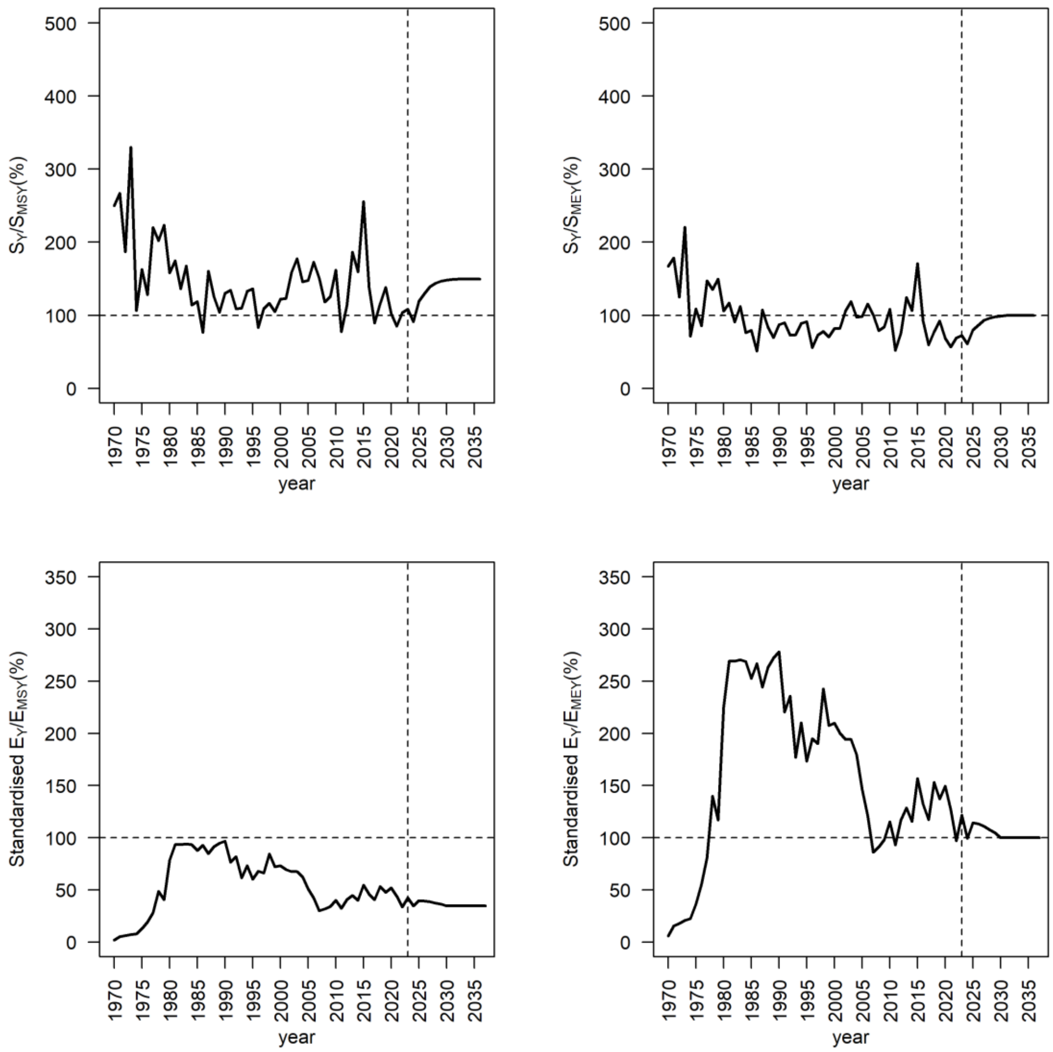


Figure 2. Status of the stock and effort relative to reference points for Brown Tiger Prawns for the Base Case.

Top-left Spawning stock size (S_Y) relative to the spawning stock size at Maximum Sustainable Yield (S_{MSY}), Top-right) spawning stock size relative to the spawning stock size at Maximum Economic Yield (S_{MEY}), Bottom-left) standardised effort (E_Y) relative to the effort at Maximum Sustainable Yield (E_{MSY}), and Bottom-right) standardised effort relative to the effort at Maximum Economic Yield (E_{MEY}). Plots were cut off at 350 for bottom two panels.

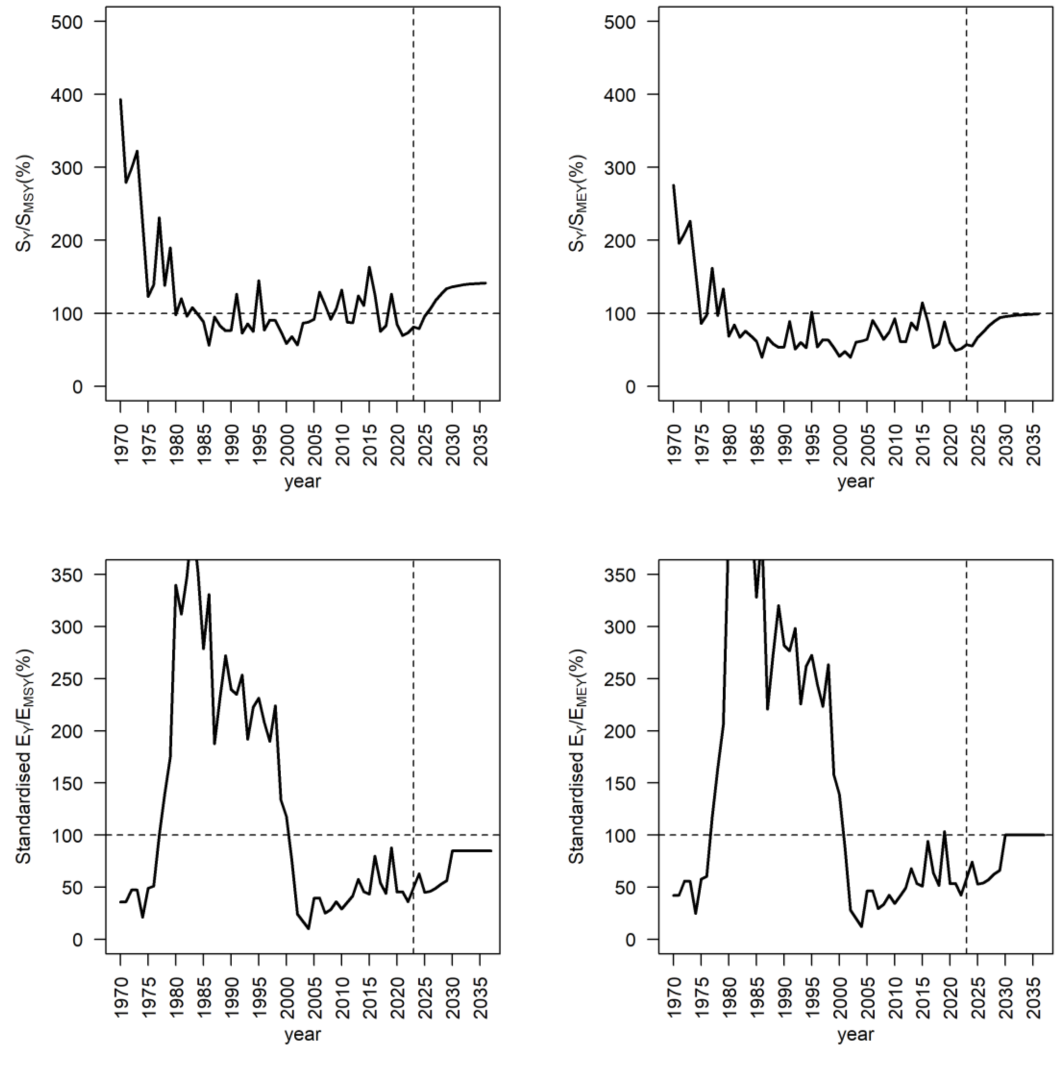


Figure 3. Status of the stock relative to reference points for Blue Endeavour Prawns for the Base Case.

a) Spawning stock size (S_Y) relative to spawning stock size at Maximum Sustainable Yield (S_{MSY}), and b) spawning stock size relative to the spawning stock size at Maximum Economic Yield (S_{MEY}).

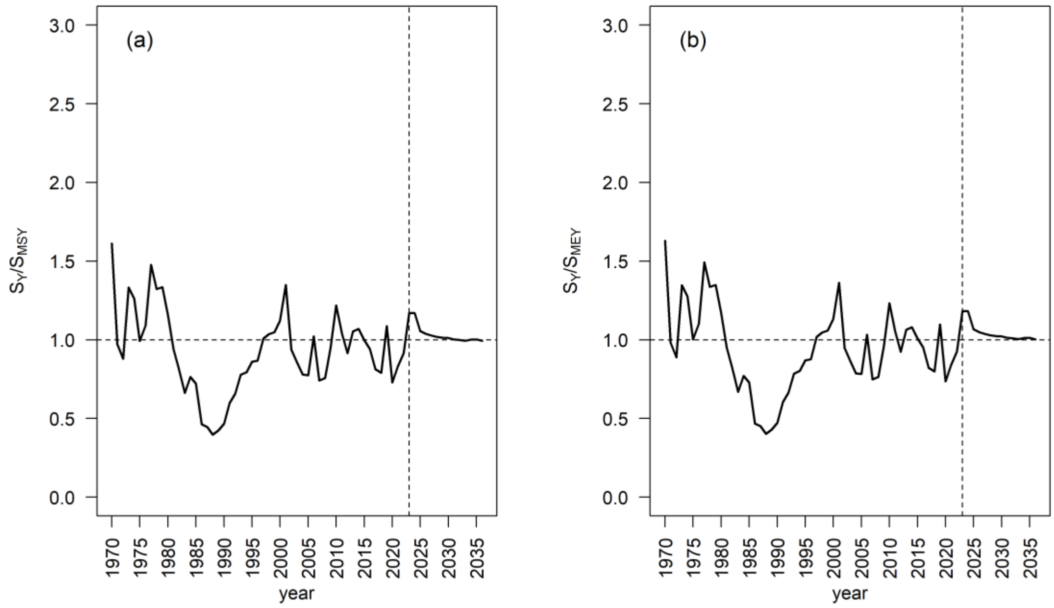


Figure 4. Status of the stock relative to reference points for Red Endeavour Prawns for the 4 species sensitivity test.

a) Spawning stock size (SY) relative to spawning stock size at Maximum Sustainable Yield (SMSY), and b) spawning stock size relative to the spawning stock size at Maximum Economic Yield (SMEY).

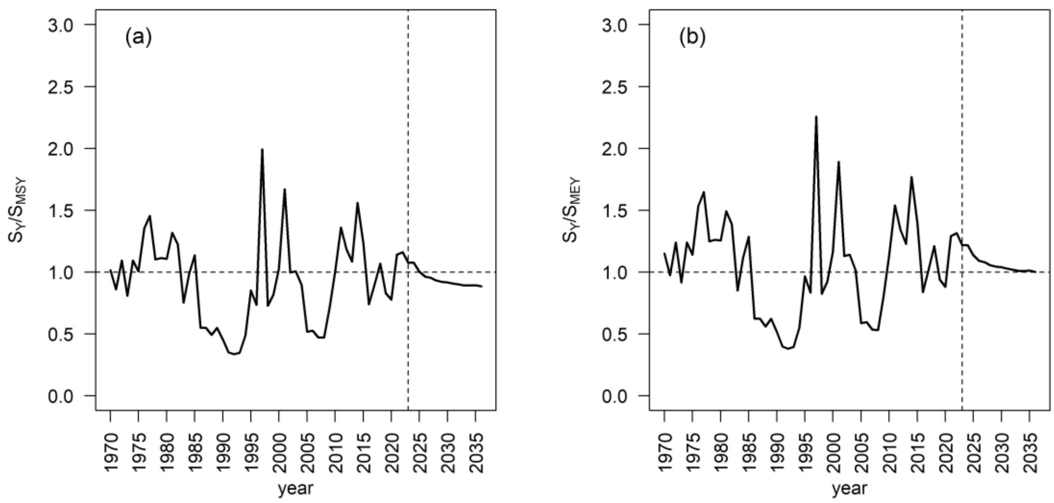


Figure 5. The key bio-economic model results (indicators) for the Base Case.

(a) Tiger Prawn effort (standardised boat days), (b) prawn catch (tonnes), (c) S_Y / S_{MSY} and (d) total projected profit (millions of Australian dollars) across all species for the Base Case assessment and projection settings.

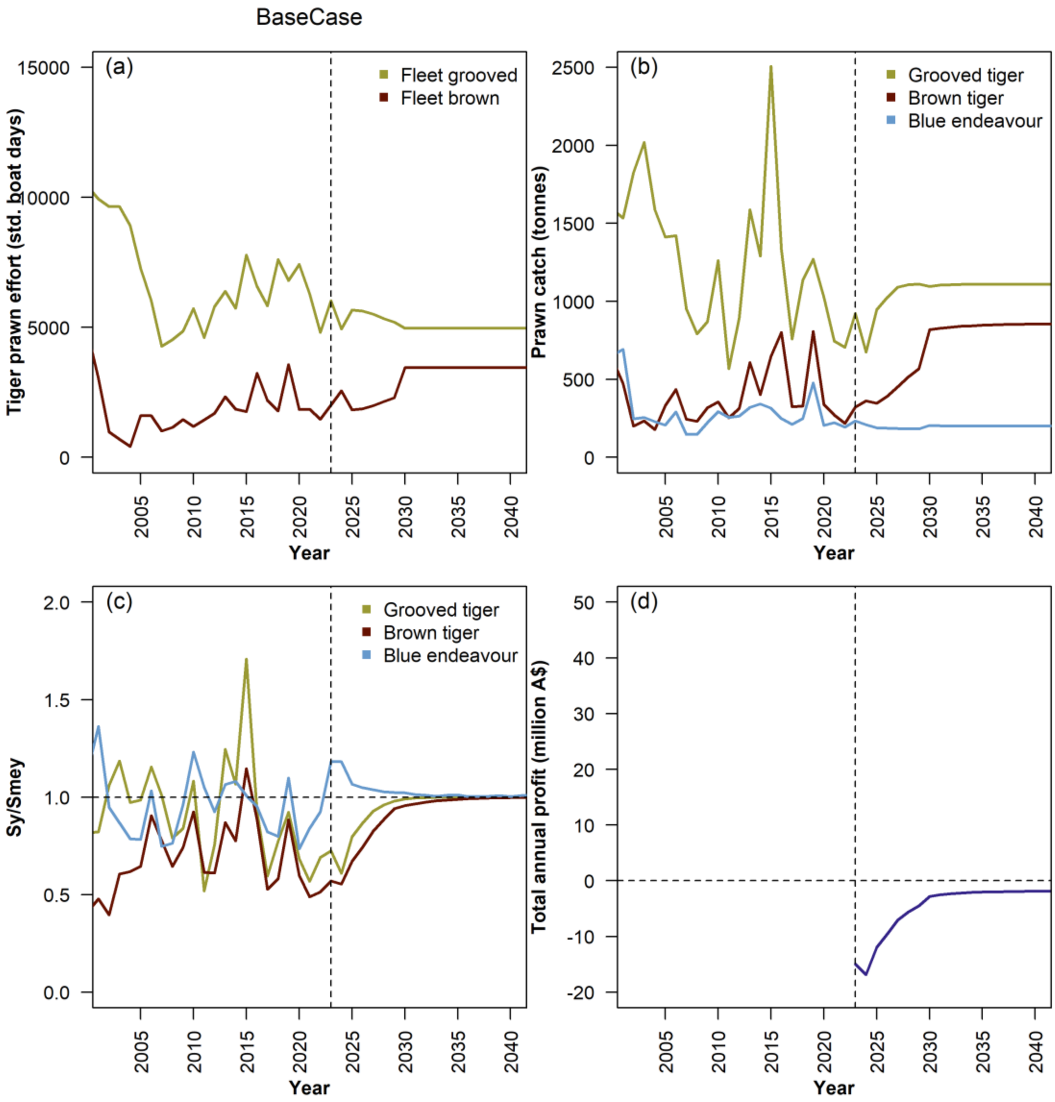


Figure 6. The key bio-economic model results (indicators) from the four species sensitivity test.

(a) Tiger Prawn effort (standardised boat days), (b) prawn catch (tonnes), (c) S_Y / S_{MEY} and (d) total projected profit (millions of Australian dollars) across all species.

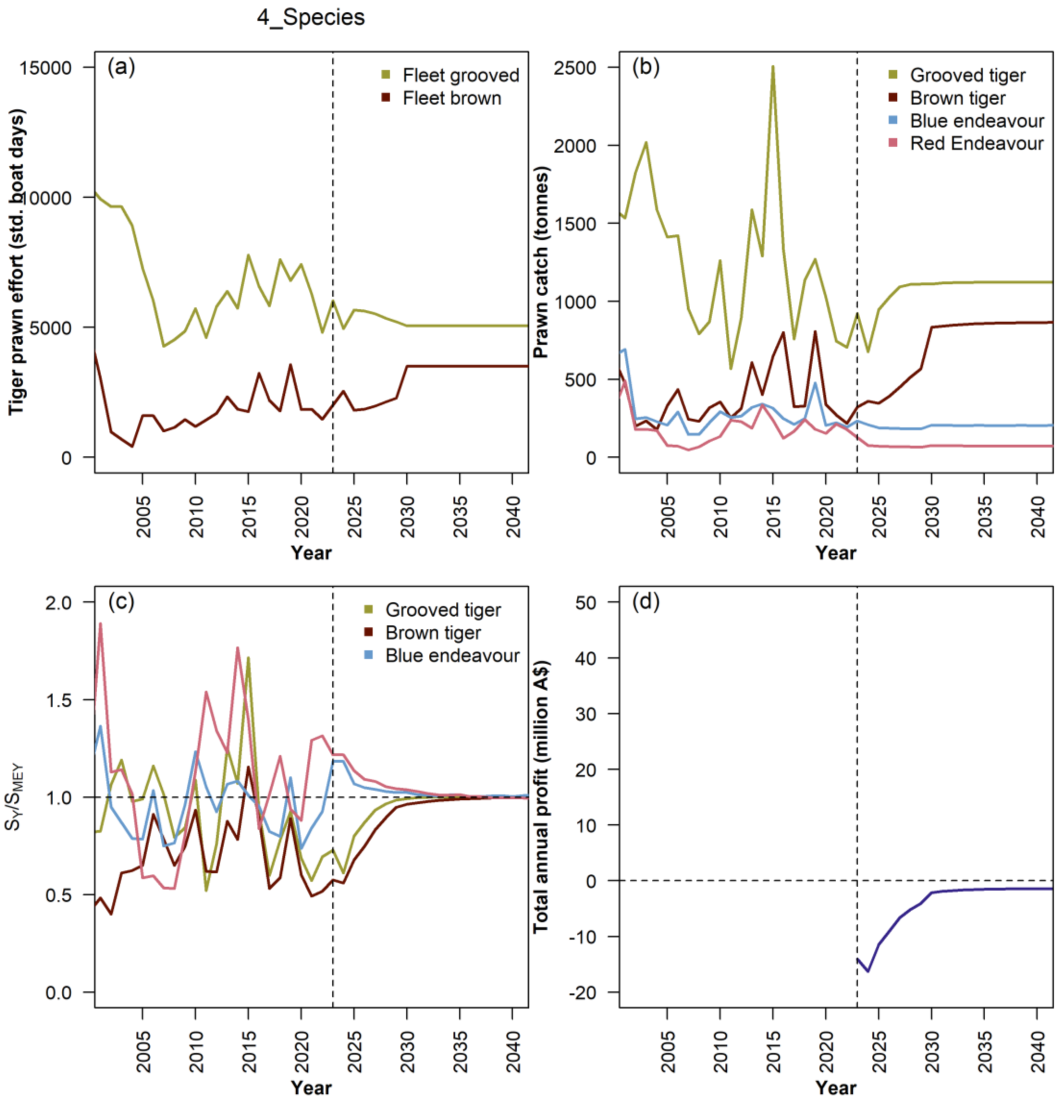


Table 1. Results of relevant management measures and parameter estimates for all three species for the "Base Case" assessment.

E_{MSY} is the effort level (expressed in terms of 2023 boat days) at which MSY is achieved and S_{MSY} is the spawner stock size at which the (deterministic) MSY is achieved. **mav = moving average**

Name	Grooved Tiger Prawns	Brown Tiger Prawns	Blue Endeavour Prawns
Steepness	0.43	0.311	NA
Catch 2024 (t)	675	361	209
Observed C2023 (t)	921	321	233
MSY (t)	1632	982	435
MEY (t)	1109	856	199
S_{MEY}/S_{MSY}	1.50	1.43	0.99
S_{2023}/S_0	0.55	0.41	1.01
S_{2023}/S_{MSY}	1.08	0.81	1.17
S_{2023}/S_{MEY}	0.72	0.57	1.18
5-year mav($S_{2019\text{-}2023}/S_{MSY}$)	1.07	0.87	0.95
S_{2030}/S_{MEY}	0.99	0.96	1.02
Observed nominal E_{2023} (day)	3314	1116	NA
Estimated nominal E_{2024} (day)	2645	1368	NA
Estimated nominal E_{2025} (day)	3036	977	NA
E_{MSY} (d)	7652	2176	NA
E_{MEY} (d)	2660	1849	NA
E_{MEY}/E_{MSY}	0.35	0.85	NA
E_{2023}/E_{MSY}	0.43	0.51	NA
E_{2023}/E_{MEY}	1.25	0.6	NA
Profit (estimated) 2023 ($m) Estimate from these 3 target species based on data provided and assumptions of fixed costs proportion to Tiger Prawn fishery versus Banana Prawn fishery. Revenue from other species (e.g. Red Endeavour Prawns, bugs, squid) not included.	-15		

Table 2. Total nominal effort for Brown and Grooved Tiger Prawn fleets, the total effort, effort change and gear change as per the NPF Harvest Strategy under input controls*.*

Note, the estimated equivalent gear changes required to get the equivalent 9.4% effort decrease from 2023, were computed using the method of Venables and Browne (2007). The TAEs (in days) were allocated across species based on the Base Case model-predicted TAE.

Year	2023 observed nominal effort (boat day)	2024 model projected effort (boat day) and changes from 2023	2025 model projected effort (boat day) and changes from 2023
Grooved Tiger Prawn nominal effort	3314	2645	3036
Brown Tiger Prawn nominal effort	1116	1368	977
Total nominal effort	4430	4013	4013
Effort change from 2023	NA	-417 (or -9.4%)	-417 (or -9.4%)
Gear change	NA	-31%	-31%

Acknowledgements

This project benefitted from consultation with, and extensive feedback from, members of the Northern Prawn Fisheries Resource Assessment Group (NPRAG). Australian Fisheries Management Authority (AFMA) and the Northern Prawn Fishery Industry (NPFI, Ltd.) are acknowledged for providing the data required for this project. Brandon Meteyard (NPFI) is thanked for checking and collating the logbook data in the required format and his significant efforts at ensuring its accuracy and completeness. Rob Kenyon, Anthea Donovan, Gary Fry, Tonya Van Der Velde, Mark Tonks and Kinam Salee from CSIRO NPF monitoring team provided abundance survey index and survey length frequency data. Tom Kompas (The University of Melbourne) analysed the economic data (provided by the NPFI). The NPRAG established the Base Case and sensitivity test criteria in February 2024. The updated fishing power series was updated owing thanks to David Sterling for the Prawn Trawl Performance Model (PTPM) results. Thanks also goes to Laura Blamey, Rob Kenyon and Jacob Rogers for internal review. The assessment was recommended by the NPRAG and was funded by the AFMA Research Fund, CSIRO and NPFI.

1 Background

The objective of the Commonwealth Fisheries Harvest Strategy Policy is the sustainable and profitable utilisation of Australia’s Commonwealth fisheries in perpetuity, through the implementation of harvest strategies that maintain key commercial stocks at ecologically sustainable levels and within this context, maximise the economic returns to the Australian community (Dichmont et al. 2012b).

The NPF has a long history of basing management decisions on the results from quantitative stock assessments (e.g., Somers, 1990; Wang and Die, 1996; Dichmont et al., 2003). Recent and future changes in management of the fishery invariably impose challenges for the provision of scientific management advice. Specifically, data-derived assessment outcomes need to be provided for the fishing strategies necessary to target the two species of Tiger Prawn. Total Allowable Effort (TAE) is the management tool of the fishery, i.e., effort is limited by a licence to fish, season length and head rope length.

Although the provision of scientific advice in multispecies fisheries is often difficult, doing so in the NPF is especially challenging because management advice needs to be based on the objective of achieving MEY rather than MSY. The advice thus requires consideration of economic as well as biological factors. In contrast, management advice in the years up to 2008 addressed an MSY objective and was based on the results of a weekly delay-difference model (Dichmont et al., 2003), fitted to catch and effort data. We interpret the MEY objective as selecting management actions to maximise the net present value (NPV), which is calculated as the difference between total revenue and costs. Important biological constraints are: (i) prawns cannot be aged, which means that methods using age-disaggregated data cannot be applied; and (ii) the short-lived nature of prawns (a maximum age of approximately 18 months) implies the need for advice on catch and effort estimates based on forecasts of stock size that strongly reflect new and strongly variable annual recruitment (as most of the stock does not survive between years).

As applied to the Northern Prawn Fishery (NPF) Tiger Prawn Fishery, the operational objective of this policy is to attain long term Maximum Economic Yield (MEY). This is implemented by maximising the net present value of the flow of profits in the fishery over a 40-year projection period. The dynamic optimisation of a seven-year path to the long-term MEY is calculated as the effort level and associated catch in each year, over a seven-year projection period that leads to a long run sustainable yield that maximises profits over time.

In this assessment, a multispecies, weekly, sex- and size-structured population model for Tiger Prawns and a Bayesian biomass production model for Endeavour Prawns are combined with an economic model that calculates profit. This system requires predictions about future fishing effort levels, the weekly allocation pattern of fishing effort and changes over time in costs and prices (Punt et al. 2011). Catches and effort for 2024 were estimated for both Tiger Prawn species given the specified harvest strategy, and then summed over the two species to produce single 2024 Tiger Prawn Fishery TAE and subsequent 2025 TAE recommendations and yearly catch estimate.

Several alternative scenarios are presented to provide sensitivity analyses for various model assumptions.

2 Needs

Based on a group of short-lived, variable-recruitment prawn species, management of the NPF requires detailed assessments to ensure maximal benefit. Specifically, under the Commonwealth Fisheries Harvest Strategy Policy, there is an agreed requirement to set TAE for Tiger Prawns and Redleg Banana Prawns. Assessment is a core element of the Harvest Strategy for the fishery. Without regular, critical updates the Harvest Strategy will need considerable change and might be ineffectual.

This project was part of the on-going assessment program for the NPF, an integral part of the management of the fishery since the 1980s. The Harvest Strategy (HS) provided harvest control rules for two species of Tiger Prawns, and two species of Endeavour prawns, and for Redleg Banana Prawns (published as a separate report). There were separate assessments for these prawns. An assessment and prediction based upon a stock-recruitment relationship was unavailable for White/Common Banana Prawns. Thus, the fishery relied on a catch rate trigger estimation procedure – which is dependent on real-time economic parameter inputs provided by Industry just prior to the beginning of the season each year; these are confidential in nature thus these are not published, but the minutes of the NPRAG meetings record the trigger limit agreed on. The calculations of the catch rate trigger were undertaken in unison. Thus, over the life of this project, the common banana prawn fishery was managed via a catch-rate trigger and season length, based upon an in-season MEY target.

The multi-species assessment of the Tiger prawn fishery (Tiger and Endeavour prawns) and the Redleg Banana Prawn fishery, required:

1. Standardisation of effort, including an annual update to the fishing power analysis; and
2. Splitting of logbook species group catch data into species.

Additionally, application of the Tiger Prawn fishery bio-economic calculations requires:

- Updated economic input values;
- Estimation of the maximum economic effort levels, via the bio-economic model; and,
- Target species abundance indices from seasonal fishery-independent surveys.

The Tiger Prawn and Redleg Banana prawn fishery models provided TAE recommendations and predicted corresponding catches, and thus made available all the information required for management.

3 Objectives

The objectives as specified in the original proposal were:

1. Provide a full assessment of the Tiger Prawn fishery for 2024 (based on 2023 fishery data). Due to the nature of stock assessment, the 2024 stock assessment will include all data up to 2023, including 2022 data (thus data collation at the end of 2022 was included as a cost);

2. Update the fishing power series incorporating data from gear surveys, annually (i.e., in 2022, 2023, and 2024 for the preceding fishing years) for both the Tiger Prawn fishery and the Redleg Banana Prawn fishery;

3. Estimate MEY-based TAEs for the Tiger Prawn fishery for each of 2024, and 2025 fishing years;

4. Assess stock status of the Redleg Banana Prawn fishery* (and relevant key environmental factors) and provide a TAE for Redleg Banana Prawns in each of 2022, 2023, and 2024; and,

5. Support annual estimation of MEY-catch rate triggers for the White/Common Banana Prawn fishery. This will be undertaken each year, i.e., 2022, 2023 and 2024.

*Published as a separate report.

4 Methods

4.1 Model structure, assumptions, and sensitivity tests

Two different groups of stock assessment models were applied: a) the Base Case, comprised of size-structured models (for two Tiger Prawn species), as well as a Bayesian biomass dynamic model (Blue Endeavour Prawns); and b) Deriso models (delay deference model) for each of the three species (Dichmont et al. 2003). The Deriso model does not use length frequency information.

Punt et al. (2011) provides a comprehensive overview of the combined model used as the Base Case, and in summary, the Base Case assessments have two components: (1) the stock assessment of the two Tiger Prawns plus Blue Endeavour Prawns, and (2) the bio-economic assessment (Dichmont et al. 2008, Punt et al. 2011, Deng et al. 2015). Previously, a delay difference model (Dichmont et al. 2003) was applied to the Endeavour Prawns, but this required several input parameters that were poorly estimated, particularly for Red Endeavour prawns. Therefore, the Blue Endeavour Prawn assessment and Red Endeavour Prawn assessment (for the four species sensitivity test) were undertaken with the Bayesian biomass dynamic model (Zhou et al. 2023). In the bio-economic model, Blue Endeavour Prawns (or in the four species sensitivity test, both Blue Endeavour Prawns and Red Endeavour Prawns) are treated as an economic byproduct i.e., effort is not directed at the species, but catches provide revenue and attract costs associated with the amount caught (such as freight and packaging). This assessment continues to include the additional fourth species (Red Endeavour Prawn) as a sensitivity test.

Various model improvements were included in the previous assessments (Deng et al, 2022; Hutton et al, 2018; Buckworth et al. 2015) based on a retrospective study of model performance (Deng et al. 2015). In addition to the mandatory data updates, the 2024 assessment incorporated several revisions. Some of these revisions were implemented because of outcomes from the NPF Tiger Prawn Fishery Adaptation Strategy Workshop Report in February 2023 (Jarrett et al., 2023). The revisions/changes/data updates for the 2024 Tiger Prawn assessment include:

- Updated logbook catch and effort data for 2022 and 2023 are added in the catch and effort time series.
- Updated monitoring survey data are added to both abundance indices, as well as the survey length frequency data. The additional survey indices are from the 2023,

and 2024 recruitment surveys and 2022 spawning survey. The length frequency data are from the 2022 and2023 recruitment surveys and 2022 spawning survey.

- Updated economic data for calendar year 2023 is incorporated, and in contrast to previous assessments the fuel cost projection is fixed at a constant fuel cost based on the April 2024 fuel price provided by NPFI. Prawn price projection is also assumed as constant (fixed) at the 2023 observed values.
- A new species splitting model (Parker et al., 2023) is applied to the entire catch and effort time series (1970-2023) to build species-specific catch and effort data. These provide fundamental input data for the Tiger Prawn and the Endeavour Prawn stock assessment models.
- The bio-economic model Minimum Effort Threshold (MET) was revised such that a combined MET value is now applied, as opposed to two separated fleet (species) MET values in previous assessments.
- The bio-economic MET was revised to be fixed at 4004 boat days, in total.
- Recently developed Blue and Red Endeavour Prawn stock assessment models (Zhou et al., 2023) were applied and integrated into the bio-economic model for the multi-species assessments in terms of MSY and MEY.
- An interannual percentage change penalty was applied to effort projections in the bio-economic model to avoid MEY projection pathways that have extremely high effort fluctuations between years. This penalty was implemented at 100% interannual effort change level, with sensitivity tests produced for 50% and 200% levels.
- Several sensitivity tests were run to ascertain the influence of various input data and model assumptions on the assessment results. These sensitivities included variations to the amount of effort change permitted between years, variations to the MET, alternative fishing power levels, model structures, predicted fishing patterns, and the inclusion of Red Endeavour Prawns in the bio-economic model (see Table A4).

The NPRAG discussed and agreed on the assessment model inputs and assumptions and defined the Base Case as the model that uses all the available data (i.e., the size-structured model for both Tiger Prawn stocks).

4.2 Input data

An updated “species-split” model (Parker et al. 2023), derived from the Tiger Prawn species distribution project, is applied in the 2024 assessment. The purpose of the splitting model is to allocate species-aggregated logbook data to species-specific catch and effort information on Tiger and Endeavour Prawns based on spatio-temporal distribution models. The species-split models were applied to all logbook data (1970-2023) to provide an update of the entire catch and effort timeseries.

Fishery independent monitoring surveys, undertaken for the Northern Prawn Fishery (NPF) since 2002, including the 2022 spawning survey, the 2023 and the 2024 recruitment surveys, provide abundance indices that are incorporated into the assessment Base Case.

Scenario “sensitivity” tests (Table 3) have mainly focused on assessing the sensitivity of the model results to assumptions regarding the factorial components of the model: fishing effort pattern, fishing power estimates, model type, constraining (year-on-year) effort change during a seven-year projection period and lowering the MET in the bio-economic model. The four-species test is to explore the capability of the model to provide a stock status of Red Endeavour Prawns.

Two updated fishing power models were applied as separate scenarios – the “low” model (used in the Base Case) and the “mid-high” model (Bishop et al. Nov 2009 and May 2010 Northern Prawn Fishery Resource Assessment Group (NPRAG)) (Figure 7 and Table Appendix B 1).

For the Base Case assessment, we used the NPRAG 2014-specified season (average of the last two years) as the fishing effort pattern (as agreed by NPRAG in March 2014 and November 2015) for the forward projection (Figure 9). See Table 3 for a description of the Base Case and various sensitivity tests.

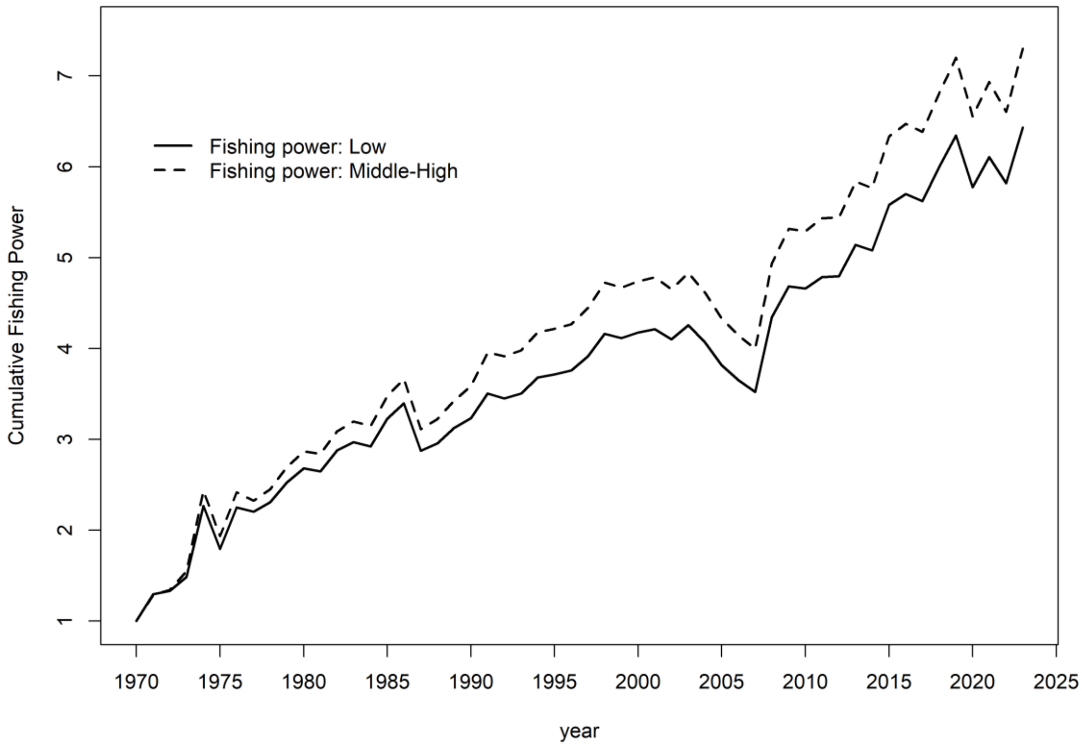
Cost and revenue parameters were provided by Prof. Tom Kompas (University of Melbourne) sourced from annual NPFI fleet vessel economic survey. So do the current prawn prices and fuel prices. Future average prawn prices were set to be same as that of 2023-2024 and future fuel unit effort costs were set as a constant based on the fuel price provided NPFI in May 2024 (NFRAG meeting, Feb 2024). The Tiger Prawn price ratio split across the different size grades is based on information provided by David Carter (Austral Fisheries Pty Ltd.) in February 2014

Table 3. Description of settings for the Base Case and sensitivity tests.

SSB indicates use of size- structured models for Grooved and Brown Tiger Prawns, and a Bayesian hierarchical model for Blue Endeavour Prawns. DDD indicates use of the Deriso model (Dichmont et al. 2003) for each species. SSBB indicates use of size-structured models for Grooved and Brown Tiger Prawns, and Bayesian hierarchical model for two Endeavour Prawns. An additional preliminary model run exploring assumptions regarding changes in catchability was undertaken for Blue endeavour prawns (see Appendix A).

Scenario name	Models	Fishing power	Weekly pattern	Max. effort change#	Combined low effort threshold	No. of species **
Base Case	SSB	Low	Last 2-year average	100%	4004	3
Mid-High Fishing Power	SSB	Mid-High	Last 2-year average	100%	4004	3
DDD	DDD	Low	Last 2-year average	100%	4004	3
Estimate season	SSB	Low	Estimated	100%	4004	3
No Constraining effort change	SSB	Low	Last 2-year average	NA	4004	3
Constraining effort change 50%	SSB	Low	Last 2-year average	50%	4004	3
Constraining effort change 200%	SSB	Low	Last 2-year average	200%	4004	3
No effort threshold	SSB	Low	Last 2-year average	100%	1	3
Base case plus red endeavour prawn	SSBB	Low	Last 2-year average	100%	4004	4

Figure 7. Two estimated cumulative fishing power series: the low fishing power and the mid-high fishing power (Appendix B).



Given the substantial data input into the assessment, a series of outputs is provided for each species (Appendix A). Although there are results for three species for the Base Case and for four species for one sensitivity test, effort-related results are only provided for the Tiger Prawns. This is because Blue and Red Endeavour Prawns (the latter only in sensitivity) are treated as an economic byproduct in the economic projection model. Modelled effort for the Tiger Prawn fishery is determined by total revenue (which includes Blue Endeavour Prawns (and Red Endeavour in the four-species sensitivity test)) and fishing costs, with effort-related costs driven largely by Tiger Prawn catches, and any additional costs associated with producing all catch (including the Endeavour species) such as crew shares, packaging and freight costs.

The results can be broadly divided into two groups: stock status-related results (e.g., stock status relative to MSY-based reference points, steepness etc.), which include the results related to the Limit Reference Point, and the economic-related results (e.g., MEY series, including application of the Harvest Strategy required to calculate the effort for 2024 and 2025) and the status relative to the Target Reference Point.

The Target Reference Point is the spawning stock size that would be achieved at the Maximum Economic Yield (MEY) and the Limit Reference Point is at the most recent five-year moving average of the spawning stock size relative to half of S_{MSY} (NPF Harvest Strategy under input controls (Dichmont *et al*. 2012b)).

5 Results

5.1 Catch and effort data

Catch and effort data from 1970 to 2023 were extracted from AFMA's logbook database for each Tiger Prawn species and for Blue Endeavour Prawns (and Red Endeavour in the four-species sensitivity test). Compared with the data of 2022, the 2023 Tiger Prawn species-combined catch increased 35% (from 924t to 1,243t) while the corresponding effort increased by 21% from 3,664 to 4,430 boat days (Table 4). The nominal effort targeting Grooved Tiger Prawns increased by about 18% from 2,812 days to 3,314 days, and that targeting Brown Tiger Prawns increased 31% from 852 days to 1,116 days from 2022 to 2023.

Table 4. Catch (tonnes) and nominal effort (boat-days) for the two species of Tiger Prawns and Blue Endeavour Prawns in the NPF since 1993.

	Catch (tonnes)				Nominal effort (boat days)		Total	
Year	Grooved Tiger	Brown Tiger	Blue Endeavour	Red Endeavour	Effort Grooved	Effort Brown	Tiger Prawn Catch	Total effort
1993	1,281	1,252	618	135	8,687	7,723	2,533	16,410
1994	1,752	1,407	680	211	9,884	8,697	3,159	18,581
1995	1,584	2,555	763	416	8,008	8,763	4,139	16,771
1996	1,082	1,266	919	374	8,896	7,794	2,348	16,690
1997	1,337	1,367	875	1,067	8,409	6,927	2,704	15,336
1998	1,692	1,594	1,011	336	10,120	7,754	3,285	17,874
1999	1,364	806	633	253	8,618	4,540	2,170	13,158
2000	1,589	630	655	309	8,646	3,987	2,219	12,633
2001	1,534	474	692	491	8,156	2,501	2,009	10,657
2002	1,818	198	247	177	8,067	807	2,017	8,874
2003	2,025	235	256	181	7,880	568	2,260	8,448
2004	1,586	179	229	172	7,505	349	1,765	7,854
2005	1,416	332	207	77	6,484	1,408	1,748	7,892
2006	1,420	437	290	73	5,629	1,496	1,857	7,125
2007	952	245	148	47	4,161	982	1,197	5,143
2008	790	231	147	68	3,763	989	1,021	4,752
2009	867	316	222	105	3,639	1,102	1,183	4,741
2010	1,277	358	294	134	4,228	874	1,635	5,102
2011	562	252	256	237	3,344	1,049	814	4,393

2012	893	312	265	230	4,174	1,221	1,205	5,395
2013	1,593	608	319	187	4,345	1,615	2,201	5,960
2014	1,286	402	343	335	3,880	1,249	1,688	5,129
2015	2,520	649	316	238	4,911	1,127	3,169	6,038
2016	1,334	804	250	124	3,988	1,973	2,139	5,961
2017	756	323	212	168	3,555	1,333	1,079	4,888
2018	1,134	330	249	243	4,440	1,048	1,463	5,488
2019	1,274	813	476	180	3,741	1,975	2,087	5,716
2020	1,028	338	205	154	4,329	1,060	1,366	5,389
2021	744	270	223	213	3,599	1,066	1,014	4,665
2022	707	217	195	177	2,812	852	924	3,664
2023	921	321	233	127	3,314	1,116	1,243	4,430

By applying the low fishing power series (Figure 7) used in the Base Case, the 2023 standardised effort for Grooved Tiger Prawns increased about 30% from 2022. For Brown Tiger Prawns, standardized effort increased about 45% from 2022 to 2023 (Table 5).

Of more importance, given the structural changes and the economic conditions in the fishery which make the interpretation of long-term trends in catch and effort data alone difficult to interpret, standardized catch rates for Grooved and Brown Tiger Prawns are steady from 2022 to 2023: the low fishing power series implies flat trend for Grooved Tiger Prawns and a 2% increase for Brown Tiger Prawns, from 2022 to 2023. By comparison, the 2023 recruitment indices from the fishery-independent survey showed a 35% increase for Grooved Tiger Prawns, and a 63% increase for Brown Tiger Prawns from 2022 to 2023 (Table 6). The most recent (2024) recruitment survey index indicates a moderate increase for Grooved Tiger Prawns (13%) but substantial decrease for Brown Tiger Prawns (51%) from that observed in 2023. Table 7 shows the time series of the spawning survey index (the spawning survey was not undertaken during 2010 and taken every two years from 2015 onwards).

Figure 8 shows the mean Catch per Unit of Effort (CPUE) indices derived from CPUEs estimated from two standardised fishing efforts based on the new fishing power series and the nominal effort. It also shows the survey-based recruitment and spawning indices.

Table 5. Standardised effort (standardised boat-days) and standardised catch-per-unit of effort (CPUE in kg per standardised boat-day) for each species of Tiger Prawn in the NPF since 1993.

Fishing power is calculated using the Low series (the Base case) of the updated fishing power analyses (Upston et al. 2022; Appendix B).

Low series fishing power	Standardised effort (standardised boat-days)		Standardised CPUE (kg per standardised boat days)		Totals	
Year	Grooved	Brown	Grooved	Brown	Standardised effort	Standardised CPUE
1993	8,687	7,723	147	162	16,410	154
1994	10,379	9,133	169	154	19,512	162
1995	8,489	9,290	187	275	17,779	233
1996	9,544	8,362	113	151	17,905	131
1997	9,395	7,739	142	177	17,134	158
1998	12,019	9,209	141	173	21,228	155
1999	10,115	5,329	135	151	15,444	141
2000	10,298	4,749	154	133	15,047	147
2001	9,801	3,005	157	158	12,806	157
2002	9,437	944	193	210	10,381	194
2003	9,569	690	212	341	10,259	220
2004	8,706	405	182	441	9,110	194
2005	7,061	1,533	201	216	8,594	203
2006	5,864	1,558	242	280	7,422	250
2007	4,179	986	228	248	5,165	232
2008	4,667	1,226	169	188	5,893	173
2009	4,865	1,473	178	214	6,338	187
2010	5,622	1,162	227	308	6,784	241
2011	4,566	1,432	123	176	5,999	136
2012	5,710	1,670	156	187	7,380	163
2013	6,375	2,370	250	257	8,745	252
2014	5,624	1,810	229	222	7,434	227
2015	7,820	1,795	322	362	9,615	330
2016	6,488	3,210	206	251	9,698	221
2017	5,705	2,139	133	151	7,844	138
2018	7,595	1,793	149	184	9,388	156
2019	6,771	3,574	188	227	10,345	202
2020	7,133	1,747	144	194	8,879	154
2021	6,272	1,858	119	145	8,130	125
2022	4,669	1,415	151	153	6,083	152
2023	6,082	2,048	151	157	8,130	153

Figure 8. Mean Catch-per-unit effort index from standardised effort series based on the low and mid-high fishing power series.

Grooved Tiger Prawns (Top-left), Brown Tiger Prawns (Top-right), Blue Endeavour Prawns (Bottom-left), and Red Endeavour Prawns (Bottom-right). The CPUE index from 1993 to 2023 is calculated using the standardised effort. The recruitment and spawning indices (no/hectare) from the fishery-independent survey are also provided for each stock (with an extension to include the 2023-2024 recruitment survey indices and additional 2022 spawning survey indices).

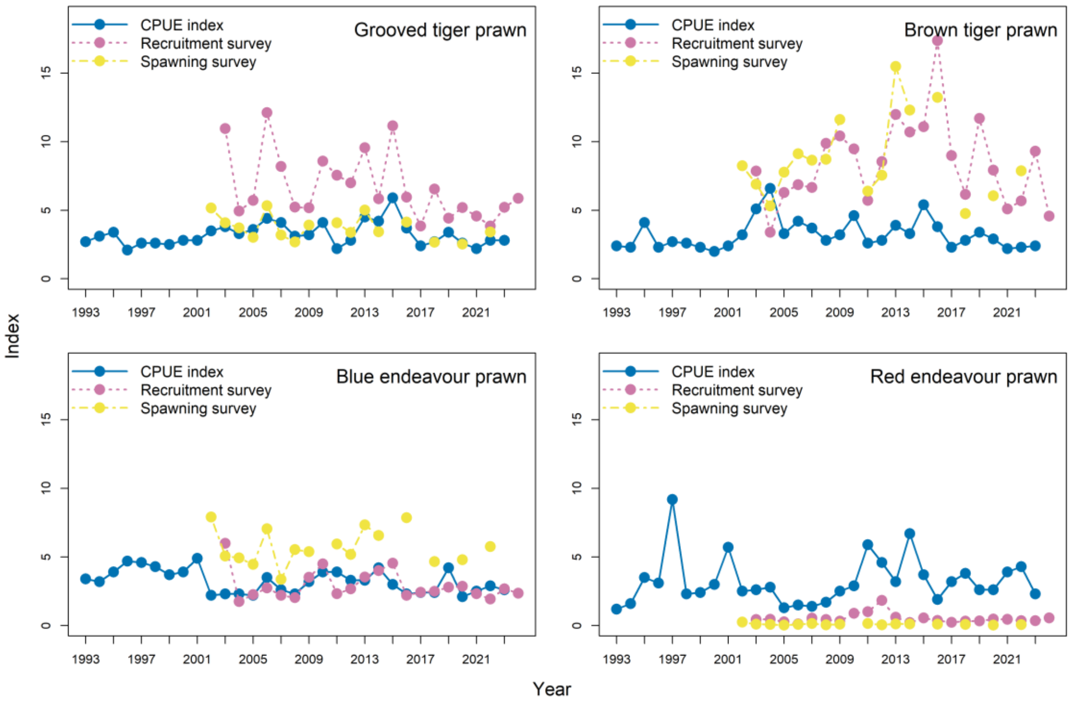


Table 6. Survey recruitment index series.

	Grooved Tiger Prawns		Brown Tiger Prawns	
Year	Recruitment index	Coefficient of variation (CV)	Recruitment index	CV
2003	10.96	0.096	7.85	0.107
2004	4.94	0.076	3.40	0.074
2005	5.71	0.054	6.29	0.096
2006	12.11	0.218	6.87	0.071
2007	8.19	0.071	6.66	0.087
2008	5.23	0.072	9.87	0.091
2009	5.18	0.071	10.41	0.087
2010	8.58	0.069	9.47	0.063
2011	7.56	0.143	5.71	0.090
2012	7.00	0.073	8.54	0.087
2013	9.56	0.092	11.98	0.097
2014	5.84	0.061	10.71	0.103
2015	11.16	0.078	11.09	0.086
2016	5.95	0.077	17.37	0.096
2017	4.85	0.061	8.9	0.088
2018	6.54	0.066	6.15	0.091
2019	4.42	0.067	11.7	0.085
2020	5.19	0.072	7.93	0.077
2021	4.58	0.067	5.10	0.074
2022	3.84	0.077	5.69	0.081
2023	5.21	0.064	9.3	0.105
2024	5.87	0.079	4.57	0.084

Table 7. Survey spawning index series.

	Grooved Tiger Prawns		Brown Tiger Prawns	
Year	Spawning index	CV	Spawning index	CV
2002	5.16	0.104	8.24	0.090
2003	4.09	0.094	6.90	0.072
2004	3.72	0.087	5.47	0.104
2005	3.02	0.098	7.77	0.078
2006	5.33	0.103	9.12	0.117
2007	3.19	0.086	8.65	0.098
2008	2.68	0.135	8.72	0.072
2009	3.92	0.107	11.61	0.082
2010	NA	NA	NA	NA
2011	4.08	0.099	6.39	0.092
2012	3.38	0.116	7.56	0.108
2013	5.01	0.080	15.48	0.106
2014	3.43	0.107	12.3	0.106
2015	NA	NA	NA	NA
2016	4.13	0.082	13.22	0.092
2017	NA	NA	NA	NA
2018	2.67	0.102	4.76	0.098
2019	NA	NA	NA	NA
2020	2.53	0.111	6.06	0.142
2021	NA	NA	NA	NA
2022	3.41	0.100	7.87	0.077
2023	NA	NA	NA	NA

5.2 Fishing Patterns

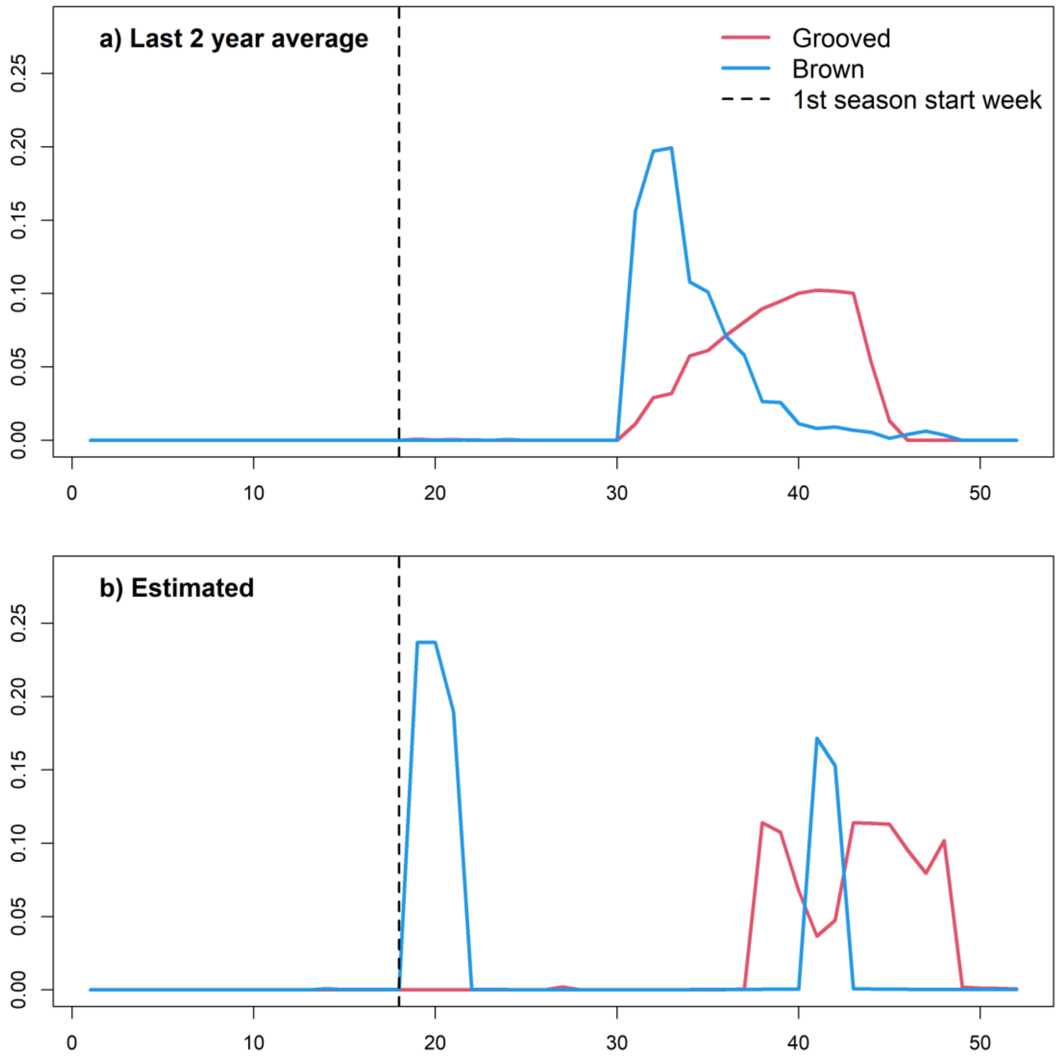
Figure 9 shows the three fishing patterns used in the projections of the economic model:

1. Base Case fishing pattern. This is the average of last two years' effort pattern, a protocol set by NPRAG in March 2014;

2. Estimated fishing pattern (sensitivity test). This involves allowing the bio-economic model to estimate the fishing pattern to maximise the profit function in the bio-economic model (see Punt et al. 2011);

Figure 9 The relative fishing patterns.

(a) the Base Case, i.e., the average of last two years' effort pattern set by NPRAG (March 2014); (b) the pattern estimated from the bio-economic model; (b) is used to compare with Base Case as sensitivity test.



5.3 Stock status

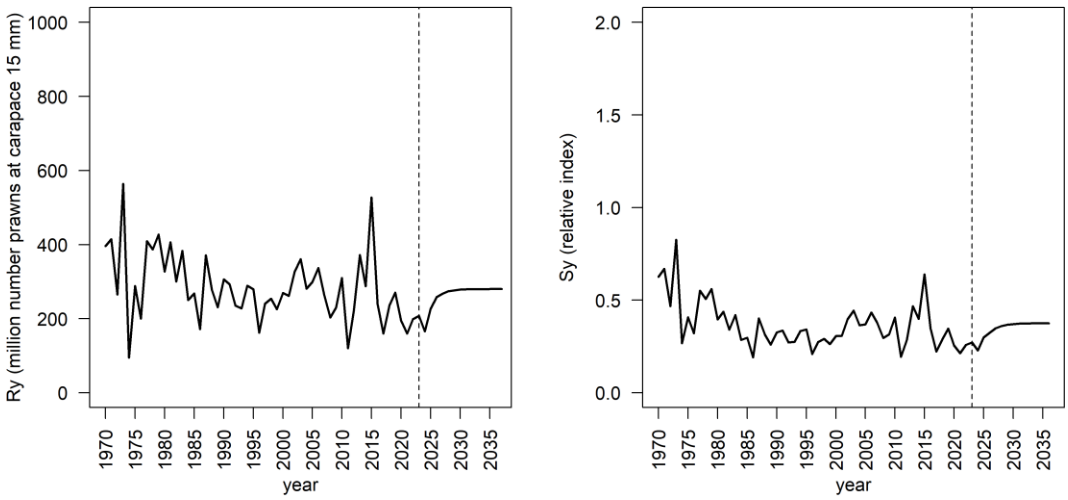
The following sections and figures describe and present the stock assessment results for Grooved Tiger, Brown Tiger Prawns, Blue Endeavour and Red Endeavour Prawns separately.

5.3.1 GROOVED TIGER PRAWNS

The assessment model estimates of Grooved Tiger Prawn annual recruitment (R_y; millions of prawns at a carapace of 15mm) are shown in Figure 10 (left panel). A moderate increase in recruitment was estimated from 2022 to 2023. The model projected a small decrease of recruitment in 2024.

Figure 10. Estimates of recruitment (left) and spawning stock size (right) for Grooved Tiger Prawns from the Base Case model.

The vertical dotted line is 2023; any values thereafter are the results of the projections from the bio-economic model based on a stock-recruitment relationship.



The estimated spawning stock size (S_y) represents a relative measure of the abundance of female prawns in spawning condition during the year based on the model. The 2023 spawning stock size of Grooved Tiger Prawns was also moderately higher than that in 2022 and is projected to be decreased in 2024 under deterministic projections and the assumption that recruitment is given by the stock-recruitment relationship (Figure 10) (right panel).

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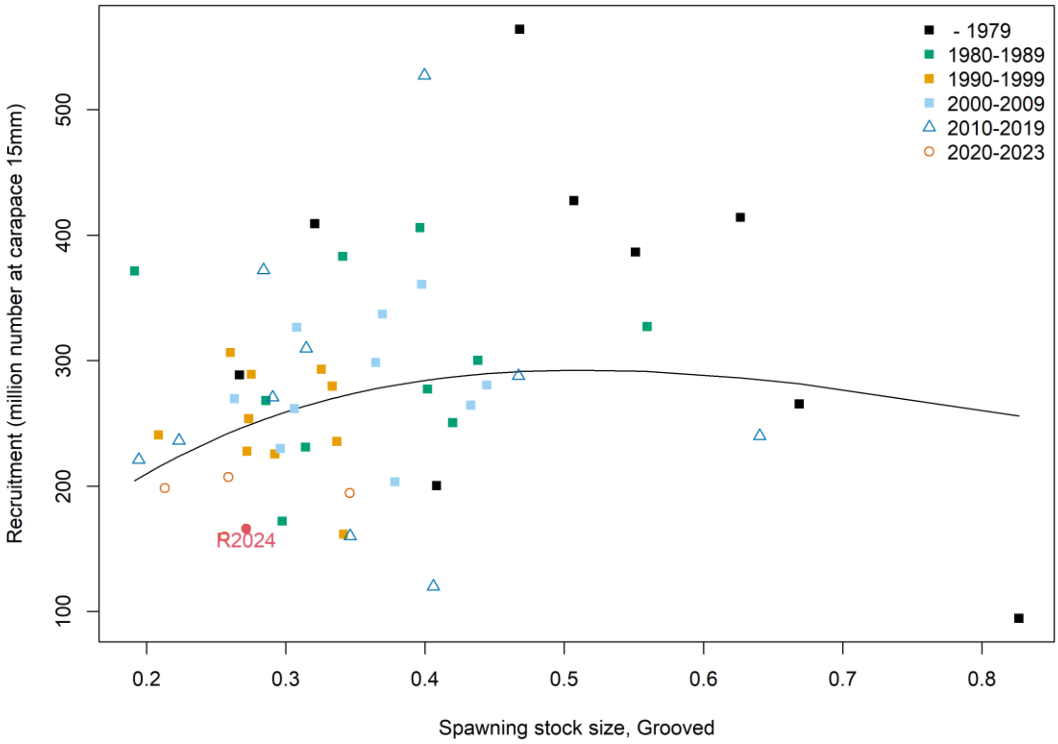
Figure 11. Estimated annual stock biomass size that produced recruits (dots), fitted as a stock-recruitment relationship (line) for Grooved Tiger Prawns for the Base Case.

The red circle with label "R2024" indicates the estimated 2023 spawning stock size and the resultant 2024 recruitment value.



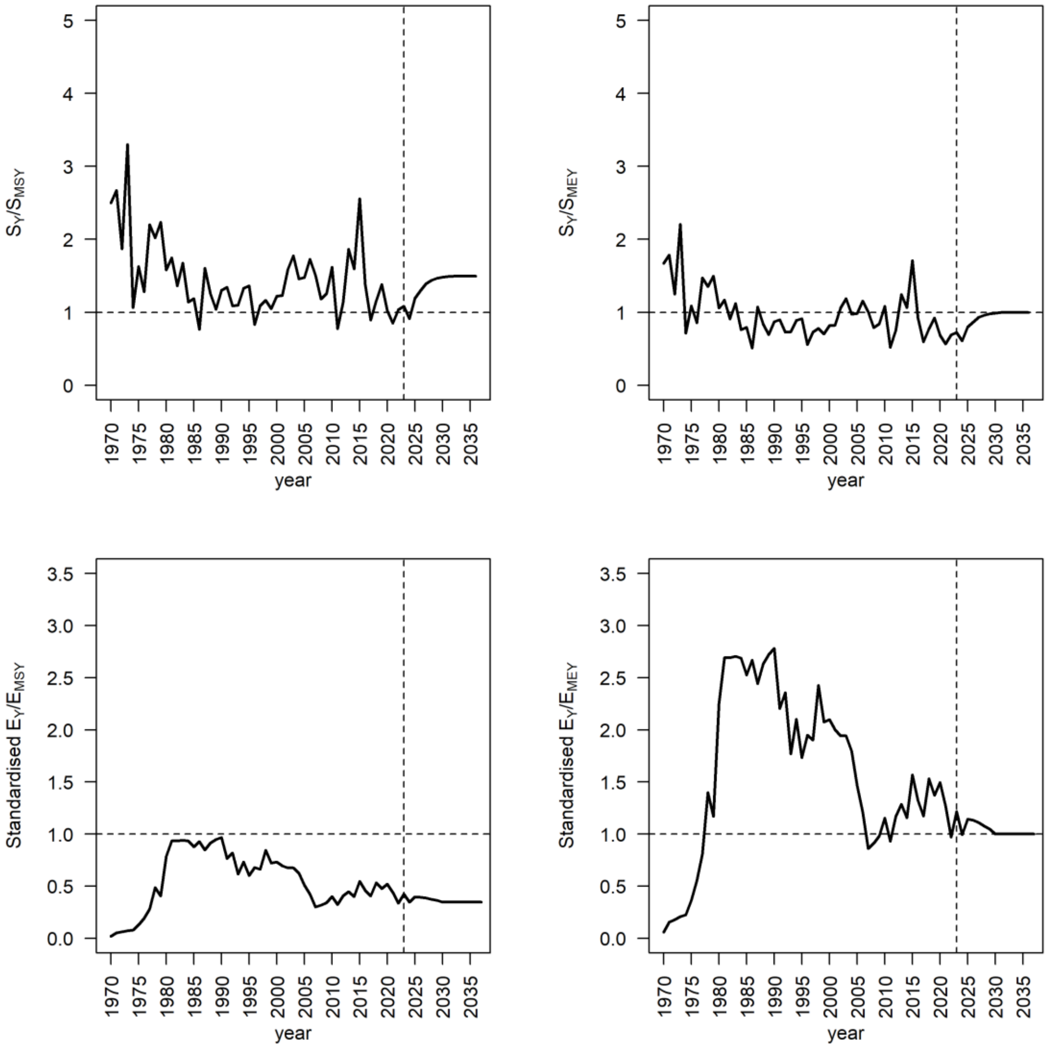
The Grooved Tiger Prawn management parameters and other quantities reported below are based on the stock-recruitment function, which relates the recruits that would be produced in the biological year to the spawners of the previous calendar year (Figure 11). Steepness, calculated by fitting a stock-recruitment relationship, is an indicator of resource productivity. The estimated value of steepness suggests that Grooved Tiger Prawn productivity is low to medium (Table Appendix A 1). The large scatter of points in Figure 11 indicates that the relationship is subject to considerable variability, which is probably temporally and environmentally driven. The colour scheme used in the figure differentiates the decadal characteristics of the relationship. In general, the early data (prior to 1980; black squares) are more variable and most of the more recent data points are evenly distributed around the estimated stock-recruitment relationship. However, it should be emphasised that the last four estimates of recruitment (since 2020) are all lower than expected. This may be a trigger point for the consideration of any fundamental changes of the species' stock.

The Base Case stock status for Grooved Tiger Prawn in 2023 is S_{2023}/S_{MSY} = 1.08 (Figure A2), and the moving five-year average $S_{2019\text{-}2023}/S_{MSY}$ = 1.07. This is above the Limit Reference Point value of 0.5. Across all the scenarios tested, Grooved Tiger Prawn stock status (S_{2023}/S_{MSY}) ranged between 0.91 - 1.47 and the moving five-year average ($S_{2019\text{-}2023}/S_{MSY}$) range was 0.91 - 1.45. Thus, the 2024 stock status for Grooved Tiger Prawn is above the limit reference point of $0.5S_{MSY}$. Effort was well below that at E_{MSY}, with E_{2023}/E_{MSY} estimates ranging between 0.24 – 0.66. Grooved Tiger Prawns are therefore considered not overfished, and overfishing is not occurring.

The Punt *et al.* (2010) model calculates the reference points taking into consideration the size at which the animals are caught. Effort in the Base Case is assumed to be distributed through the year according to the average of last two years' effort patterns.

Figure 12. Status of the stock and effort relative to reference points for Grooved Tiger Prawns for the Base Case.

Top-left) Spawning stock size (S_Y) relative to the spawning stock size corresponding to Maximum Sustainable Yield (S_{MSY}), Top-right) spawning stock size relative to the spawning stock size corresponding to Maximum Economic Yield (S_{MEY}), Bottom-left) standardised effort (E_Y) relative to that corresponding to Maximum Sustainable Yield (E_{MSY}) and Bottom-right) standardised effort relative to that corresponding to Maximum Economic Yield (E_{MEY}).



5.3.2 BROWN TIGER PRAWNS

The estimates of the annual recruitment of Brown Tiger Prawns is shown in Figure 13 (left panel). Recruitment increased slightly in 2022 from 2023. The model projected a small decrease of recruitment in 2024. Estimates of Spawning stock size represent the relative number of female prawns in spawning condition during the calendar year. The estimated time-series of spawning stock size for Brown Tiger Prawns is given in Figure 13 (right panel). The estimated spawning stock size of Brown Tiger Prawns remains similar in 2022 and 2023, but is projected to be decreased slightly in 2024.

Figure 13. Estimates of recruitment (Left) and spawning stock size (Right) for Brown Tiger Prawns from the Base Case model.

The vertical dotted line is 2021; any values thereafter are the results of the projections from the bio-economic model based on a stock-recruitment relationship.

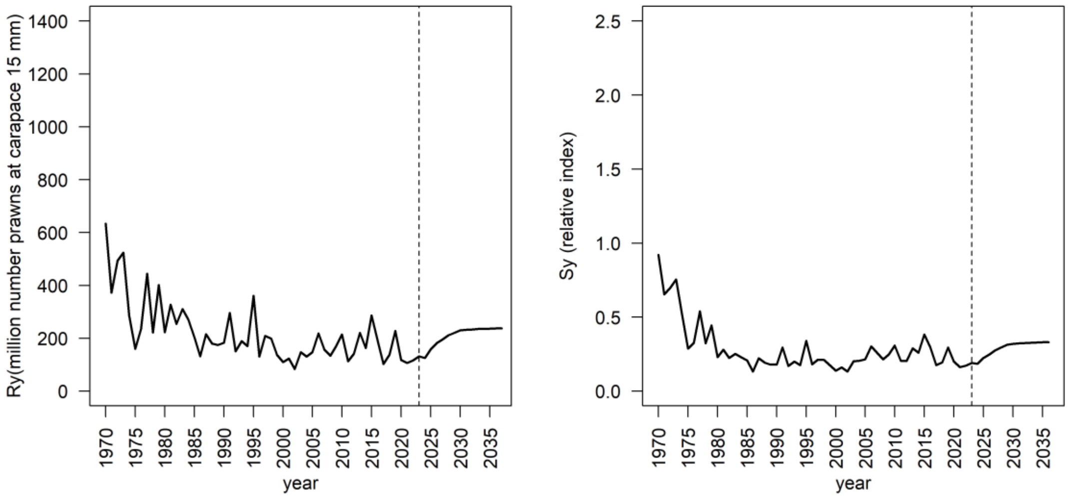
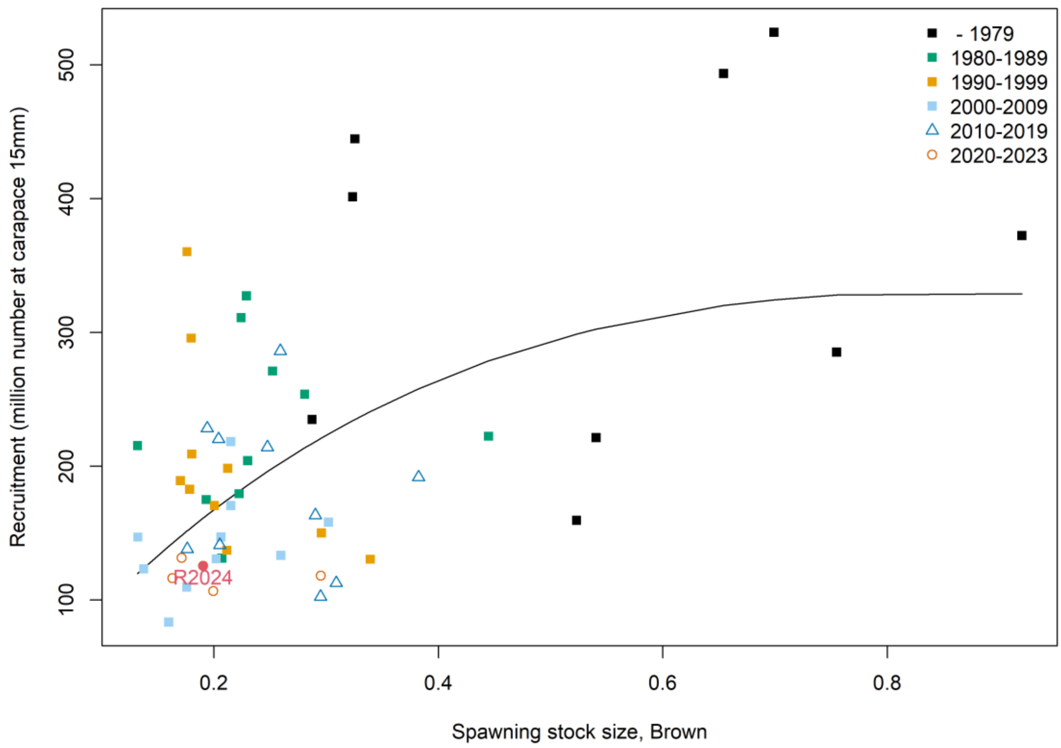


Figure 14. Estimated annual stock biomass size that produced recruits (dots), fitted as a stock-recruitment relationship (line) for Grooved Tiger Prawns for the Base Case.

The red circle with label "R2024" indicates the estimated 2023 spawning stock size and the resultant 2024 recruitment value.



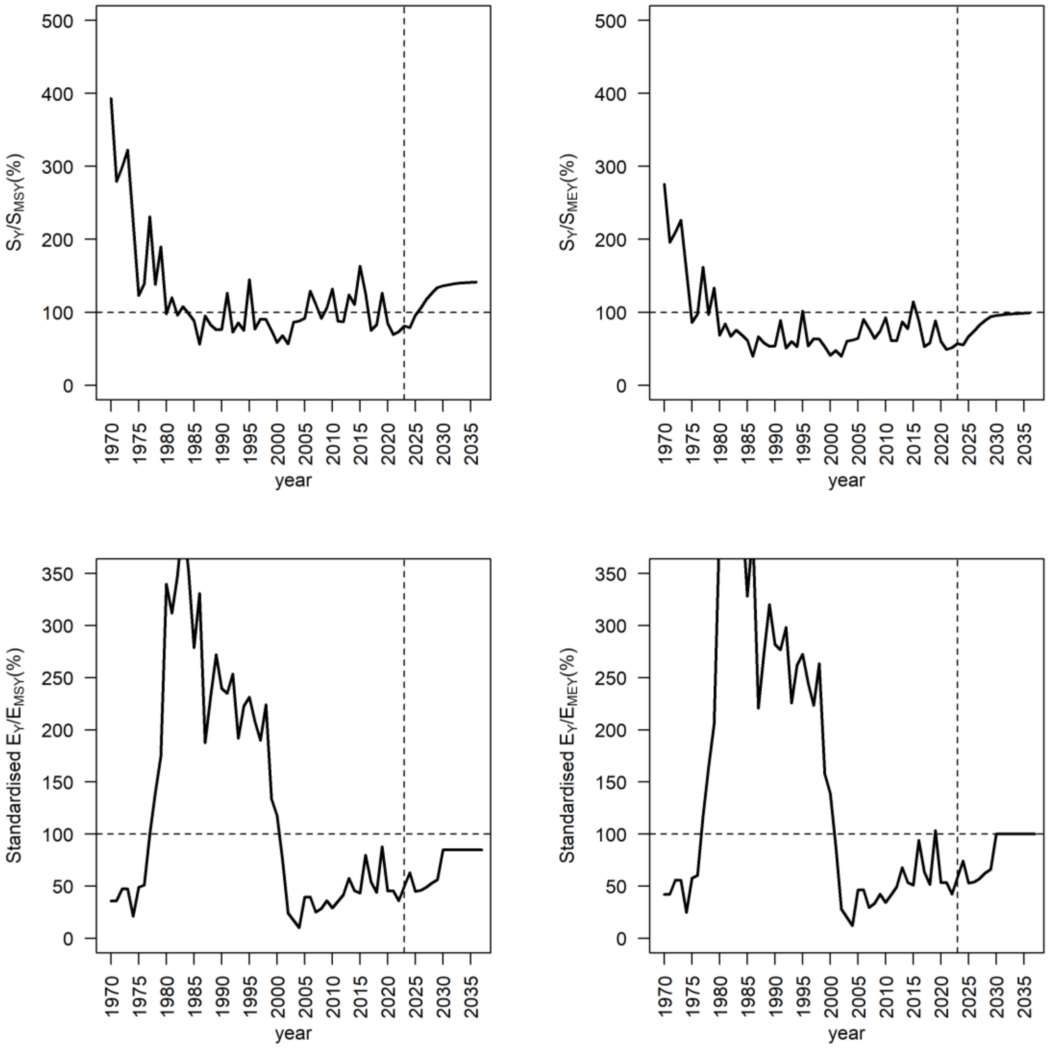
The Brown Tiger Prawns Prawn management parameters and other quantities reported below are based on the stock-recruitment function, which relates the recruits that would be produced in the biological year to the spawners of the previous calendar year (Figure 14). Estimated recruitment for 2024 is low and the estimated steepness value also suggests that Brown Tiger Prawn productivity is low (Table Appendix A 1). The 2023 stock index that resulted in the 2024 recruitment is highlighted on Figure 14. Similar to Grooved Tiger Prawns, the last 5 years of recruitment are lower than the model expected values, which suggests that there may be value in investigating whether there has been fundamental changes to the stock dynamics.

The Base Case stock status for Brown Tiger Prawn is S_{2023}/S_{MSY} = 0.81, and the moving five-year average $S_{2019-2023}/S_{MSY}$ = 0.87. The stock status (S_{2023}/S_{MSY}) ranged between 0.70 - 0.90 in all scenarios tested. Furthermore, the moving five-year average ($S_{2019-2023}/S_{MSY}$) ranged between 0.76 – 0.96, and thus above the limit reference point of $0.5S_{MSY}$. Effort was well below that at E_{MSY}, with E_{2023}/E_{MSY} estimates ranging from 0.32 to 0.57. Therefore, Brown Tiger Prawn are considered not to be overfished nor is overfishing occurring.

We note again that the Punt *et al.* (2010, 2011) model calculates the indicators whilst taking into consideration the size at which the animals are caught. Effort in the Base Case is assumed to be distributed through the year using the average of last two years' effort patterns.

Figure 15. Status of the stock and effort relative to reference points for Brown Tiger Prawns for the Base Case.

Top-left) Spawning stock size (S_Y) relative to the spawning stock size corresponding to Maximum Sustainable Yield (S_{MSY}), Top-right) spawning stock size relative to the spawning stock size corresponding to Maximum Economic Yield ($\underline{S}_{MEY}$), Bottom-left) standardised effort (E_Y) relative to that corresponding to Maximum Sustainable Yield (E_{MSY}) and Bottom-right) standardised effort relative to that corresponding to Maximum Economic Yield (E_{MEY}).

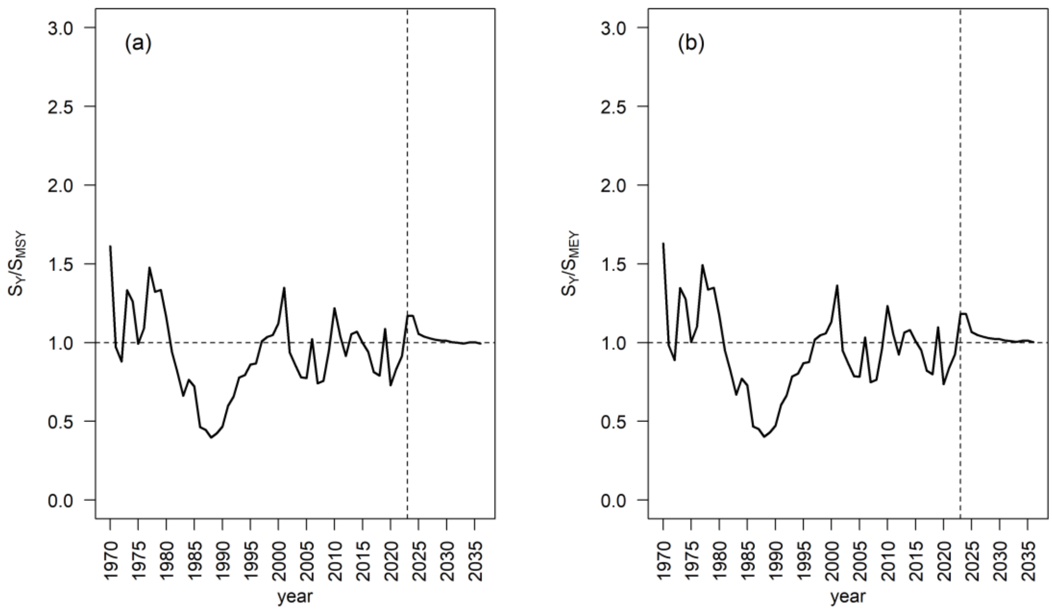


5.3.3 BLUE ENDEAVOUR PRAWNS

An assessment of Blue Endeavour Prawns is conducted using the Bayesian biomass production model (see Figure 16 and key indicators in Table Appendix A 1) noting that Blue Endeavour Prawns are treated as an economic byproduct in the economic projection model. The Base Case stock status for Blue Endeavour Prawn is S_{2023}/S_{MSY} = 1.17 (Figure 16), and the moving five-year average $S_{2019\text{-}2023}/S_{MSY}$ = 0.95. In all the sensitivity scenarios tested, the Blue Endeavour Prawn stock status (S_{2023}/S_{MSY}) ranged from 0.77 – 1.33, while the moving five-year average ($S_{2019-2023}/S_{MSY}$) ranged from 0.82 – 1.07. Blue Endeavour Prawn is, therefore, not considered to be overfished according to the limit reference point of $0.5S_{MSY}$ based on a five-year moving average.

Figure 16. Estimates of spawning stock size relative to reference points for Blue Endeavour Prawns for the Base Case.

a) Spawning stock size (S_Y) relative to spawning stock size corresponding to Maximum Sustainable Yield (S_{MSY}), b) spawning stock size relative to the spawning stock size corresponding to Maximum Economic Yield (S_{MEY}).

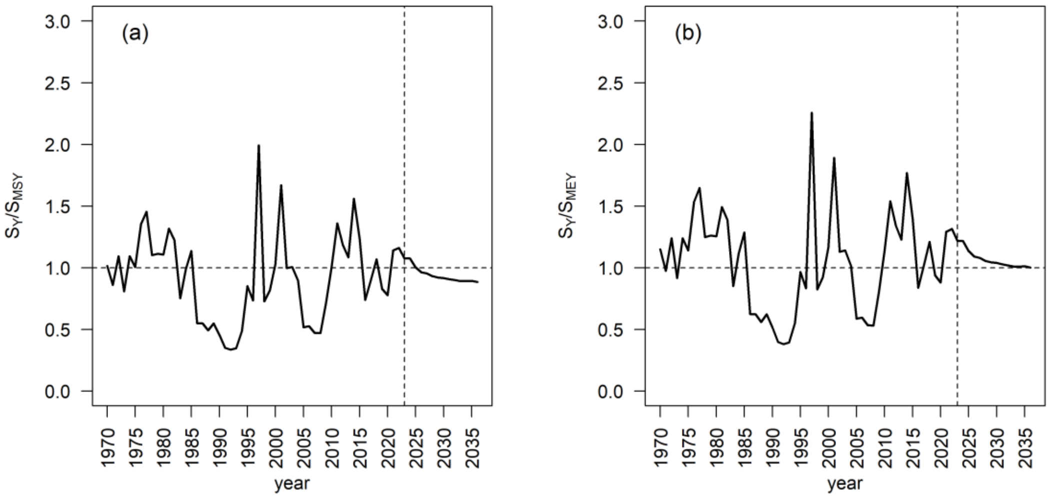


5.3.4 RED ENDEAVOUR PRAWNS

An assessment of Red Endeavour Prawns was conducted as a sensitivity test using the Bayesian biomass production model (see Figure 17 and key indicators in Table Appendix A 5). Red Endeavour Prawns are treated as an economic byproduct in the economic projection model (Figure 32). In the four species sensitivity test, the Red Endeavour stock status was S_{2023}/S_{MSY} = 1.08 (Figure A5), while the five-year moving average $S_{2019-2023}/S_{MSY}$ = 1.00. Red Endeavour Prawn is, therefore, not considered to be overfished according to the limit reference point of $0.5S_{MSY}$ based on a five-year moving average.

Figure 17. Estimates of spawning stock size relative to reference points for Red Endeavour Prawns for the 4 species sensitivity test.

a) Spawning stock size (S_Y) relative to spawning stock size corresponding to Maximum Sustainable Yield (S_{MSY}), b) spawning stock size relative to the spawning stock size corresponding to Maximum Economic Yield (S_{MEY}).



5.3.5 SENSITIVITY TESTS FOR BOTH TIGER PRAWN SPECIES

Model settings and key stock and economics-related assessment outputs are provided in Table Appendix A 2 – 5 for the four prawn species (Appendices, Appendix A).

The following scenarios explore the sensitivity of the results to assumptions of the stock assessment and bio-economic models:

- Base Case;
- Middle-high fishing power series;
- alternative assessment model (DDD);
- estimated of fishing patterns;
- No constraint applied to inter-annual effort change;
- Inter-annual effort changes constrained to 50%;
- Inter-annual effort changes constrained to 200%;
- No Minimum Effort Threshold (MET) applied; and
- Base case plus Red Endeavour Prawn (four-species model)

They show that the highest steepness (productivity) values arise from the Base Case. The DDD model produced the lowest value for steepness. The “DDD” sensitivity tests estimates a more pessimistic stock status compared to the Base Case but the relative loss, however, is 46% of Base Case for 2023. Not being a size-structured model, the Deriso models are unable to capture the price differentials between small and large prawns. The estimates of

$S_{2019\text{-}2023}/S_{MSY}$ are greater than the Limit Reference Point for the Base Case and all sensitivity test (Table Appendix A 2 – 5) so there is no evidence from these analyses that any of the four stocks are overfished. However, there are substantial differences in the values of the indicators for projected fishing effort in 2024 and relative total projected period loss (38% and 90% of the Base Case values, respectively) for "no effort threshold" sensitivity test. Given the lack of a minimum effort constraint in this sensitivity test, the model responds to the adverse economic conditions by estimating much lower fishing effort projections to maximize NPV (Table Appendix A 2).

Fishing pattern mainly affects the estimates of profitability of the fishery: the relative loss with the "estimated fishing pattern" is 51% of that of Base Case in which the fishing pattern is from the average of the previous two years fishing. The results are not very sensitive to the alternative fishing power series (Mid-high vs Base Case in Table Appendix A 2 - 4). Similarly, constraining inter-annual effort changes to 50% or 200% produces results comparable to the Base Case whereby the inter-annual effort change is allowed to fluctuate by 100%. The "no inter-annual effort change constraint" scenario also produces results similar to that of the Base Case, reaffirming model stability (the function of the inter-annual effort constraint is to avoid inconsistent effort trajectories in the MEY optimization pathway i.e., annual effort dumps).

5.3.6 MODEL FIT

The distribution of the catch residuals (square root-transformed differences between observed and estimated catches[1]) by Tiger Prawn species are shown for the Base Case in Figure 18. The residuals by week and year are shown in Figure 19-20. The weekly residual patterns are exhibit "runs" indicating that the assumptions regarding catchability and availability (estimated by month) are insufficient to capture changes in availability. In contrast, the residuals by year exhibit no obvious trends. The model is specified so that the total annual catch is removed almost exactly.

The fits to the recruitment and spawning survey index data are shown in Figure 21, which suggests that the model reproduces these data adequately. The confidence intervals in Figure 21 indicate both sampling error (Table 6 and Table 7) and additional variation. The fits to size-composition data are shown in Figure 22 - Figure 29. Some of the fits to the

[1] This transformation has been shown to be the best way to transform the data to achieve a residual distribution closest to a normal distribution (Dichmont *et al*. 2001).

fishery size-composition data are poor (e.g., Figure 23 and Figure 29). This is a long-term feature of the assessment and is attributed in part to the very limited fishery size-composition data. Figure 30 shows the estimates of biological and fishery parameters for the Base Case size-structured population model, including the recruitment seasonal availability pattern, the selectivity to the spawning and recruitment survey, and the selectivity to the fishery.

Figure 18. Distribution of the residuals (square root-transformed differences between observed and model-predicted catches) by week and year.

top) Grooved Tiger Prawns, bottom) Brown Tiger Prawns for the Base Case assessment.

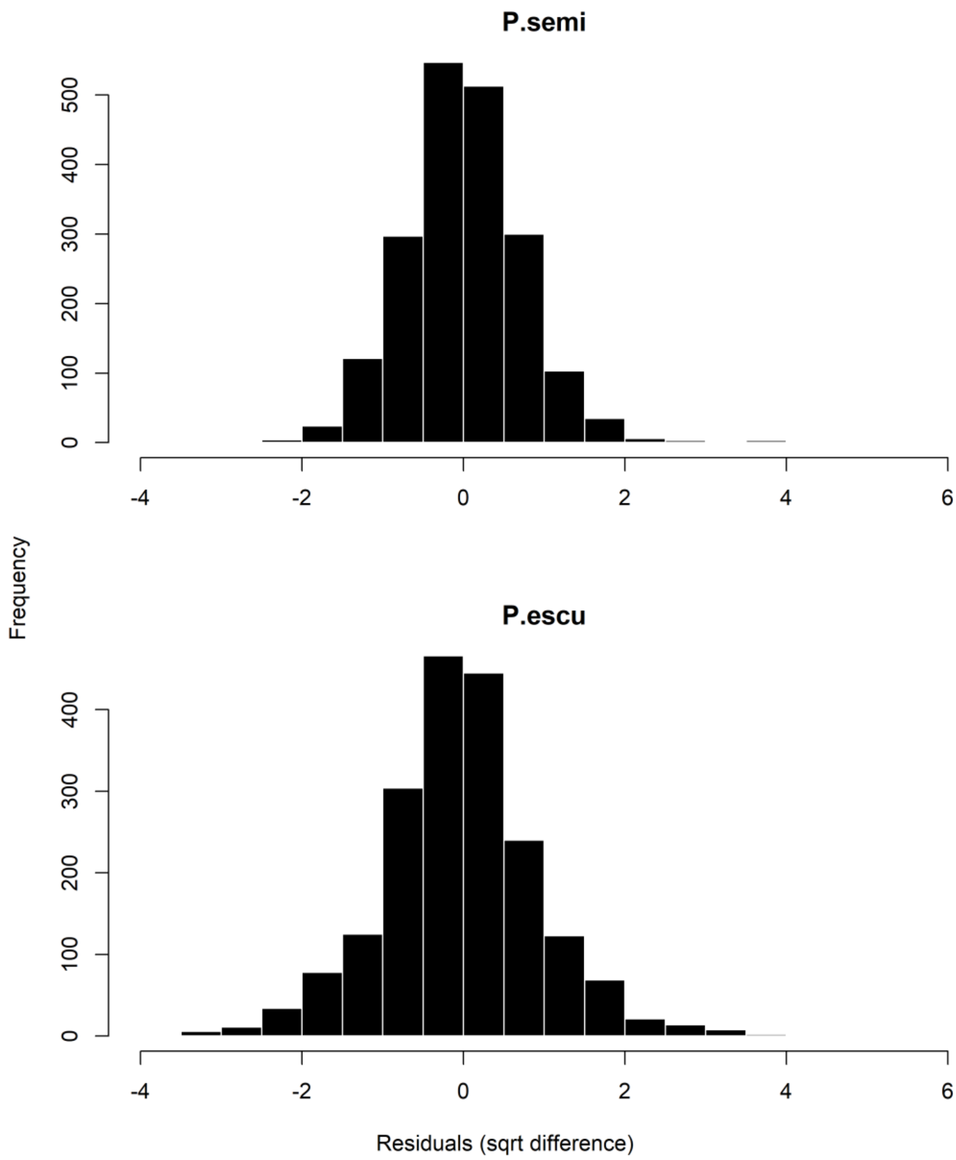


Figure 19. (a) Total, (b) weekly within-year, and (c) annual residual patterns about the fit to the catch-in weight data for Grooved Tiger Prawns (*P. semisulcatus*) for the Base Case.

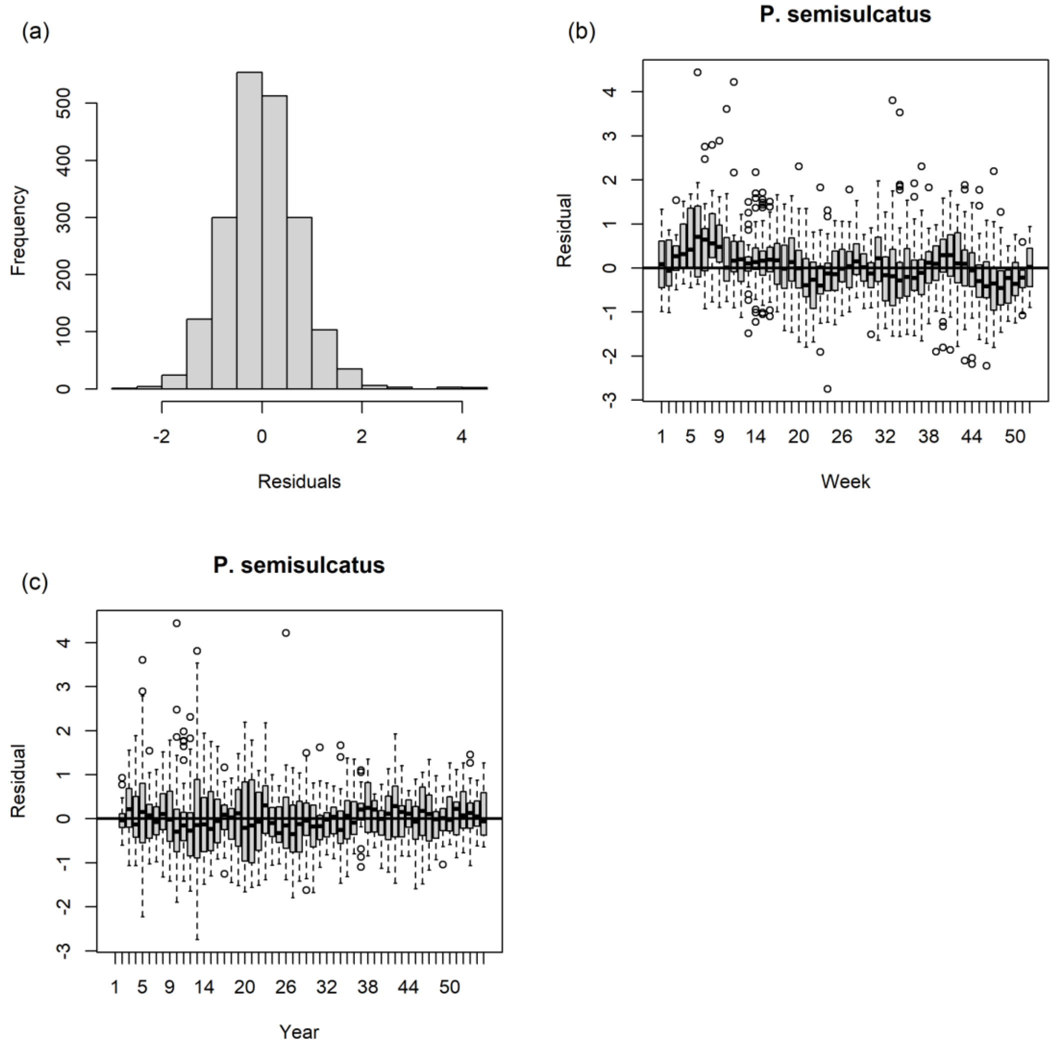


Figure 20. (a) Total, (b) weekly within-year, and (c) annual residual patterns about the fit to the catch-in weight data for Brown Tiger Prawns (*P. esculentus*) for the Base Case.

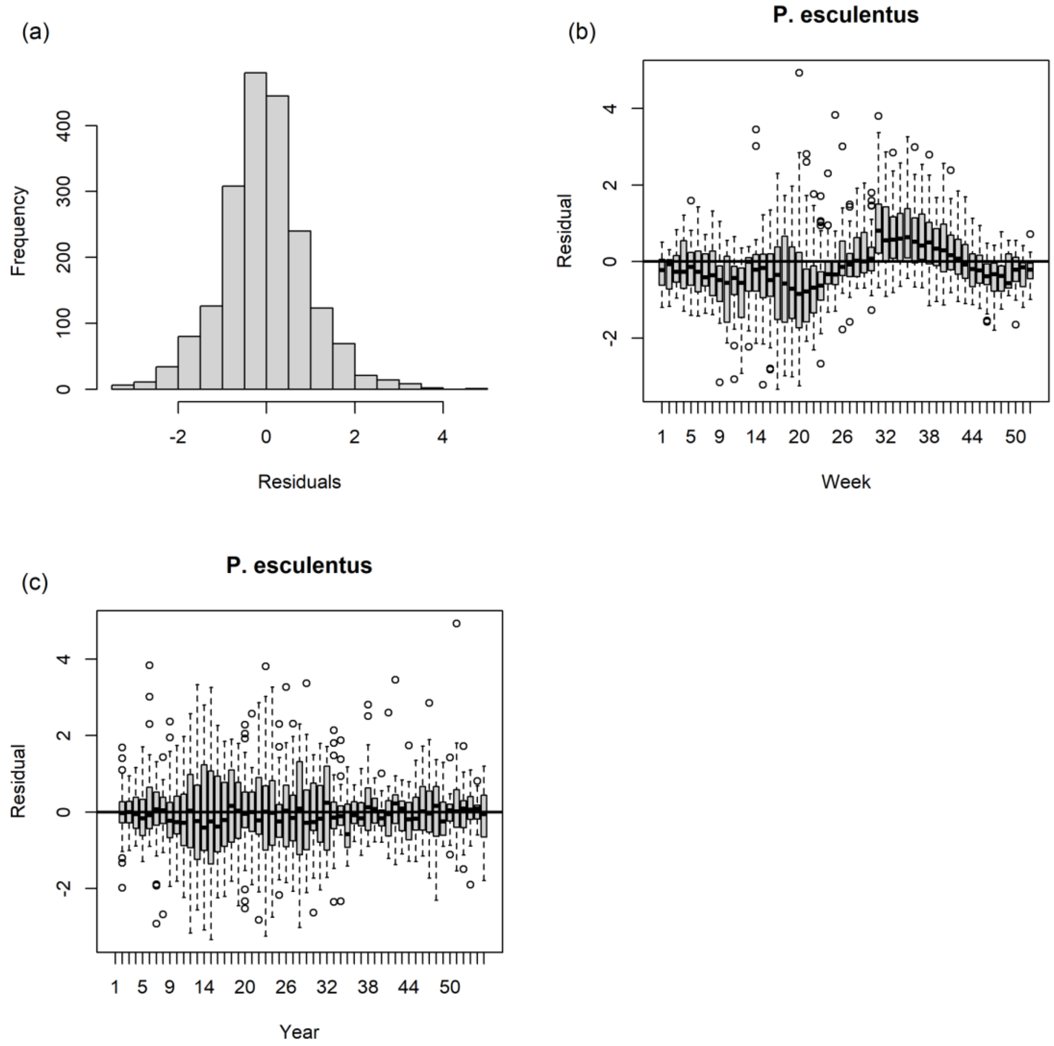


Figure 21. Observed (points as means and bars as 1 standard error) and model-predicted index data for the Grooved and Brown Tiger Prawns' recruitment (a and b, respectively) and spawning (c and d, respectively).

The confidence intervals include both sampling error and additional variance.

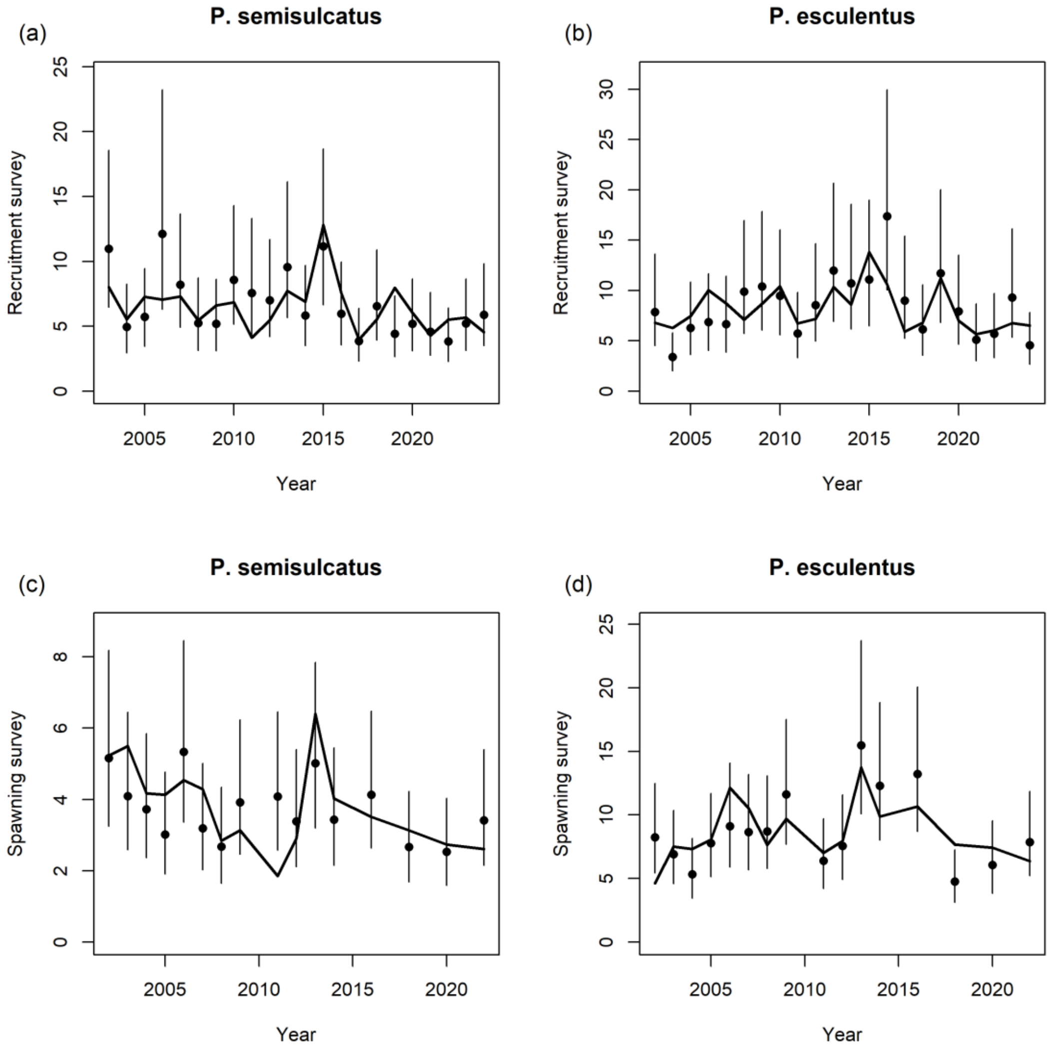
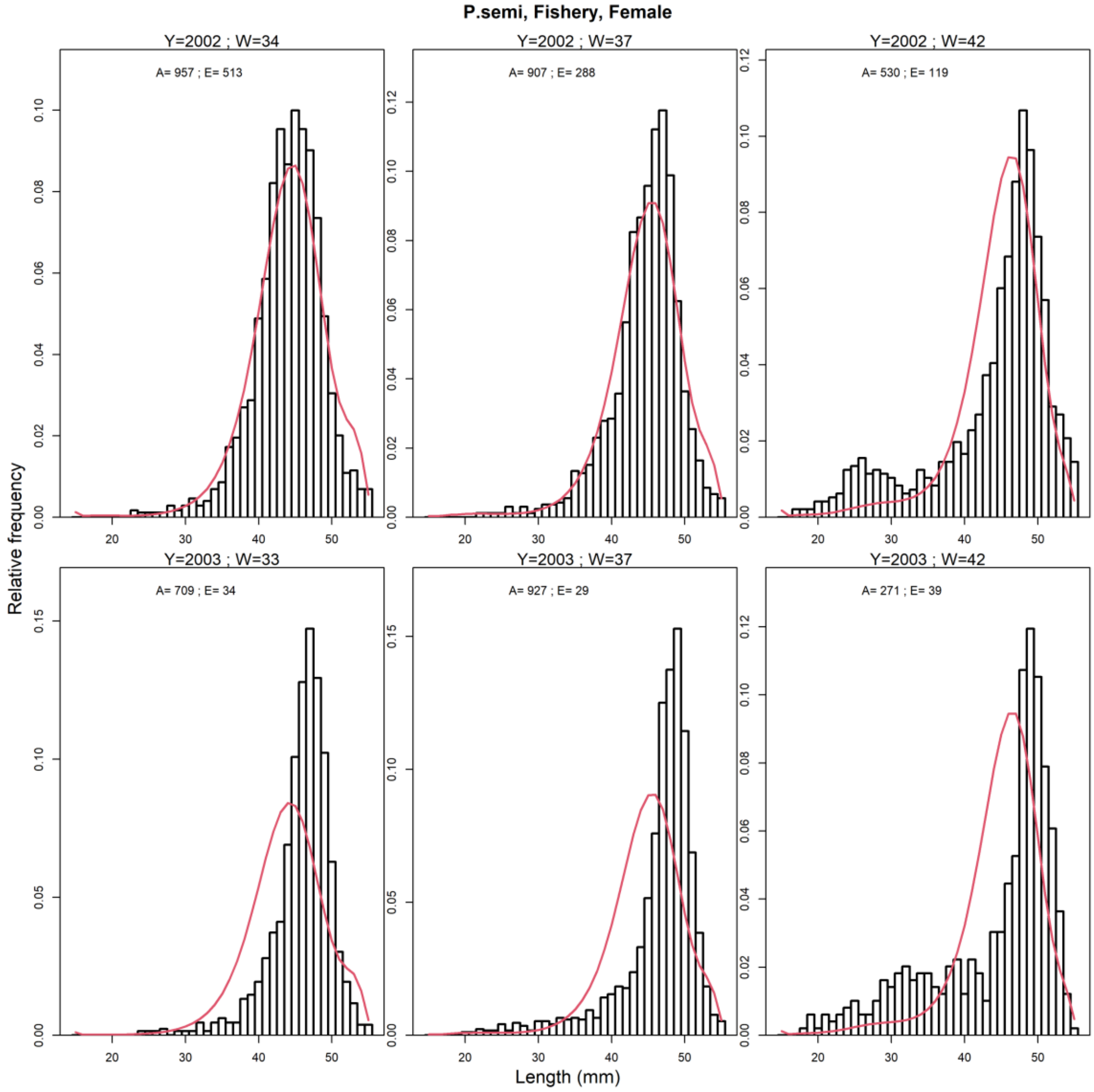


Figure 22. Observed (histograms) and model-predicted (red lines) size-compositions for the fishery for Grooved Tiger Prawns. a) female; b) male; Y = year, W = week, A = actual sample size, E = effective sample size (for all the LF plots).

a)



b)

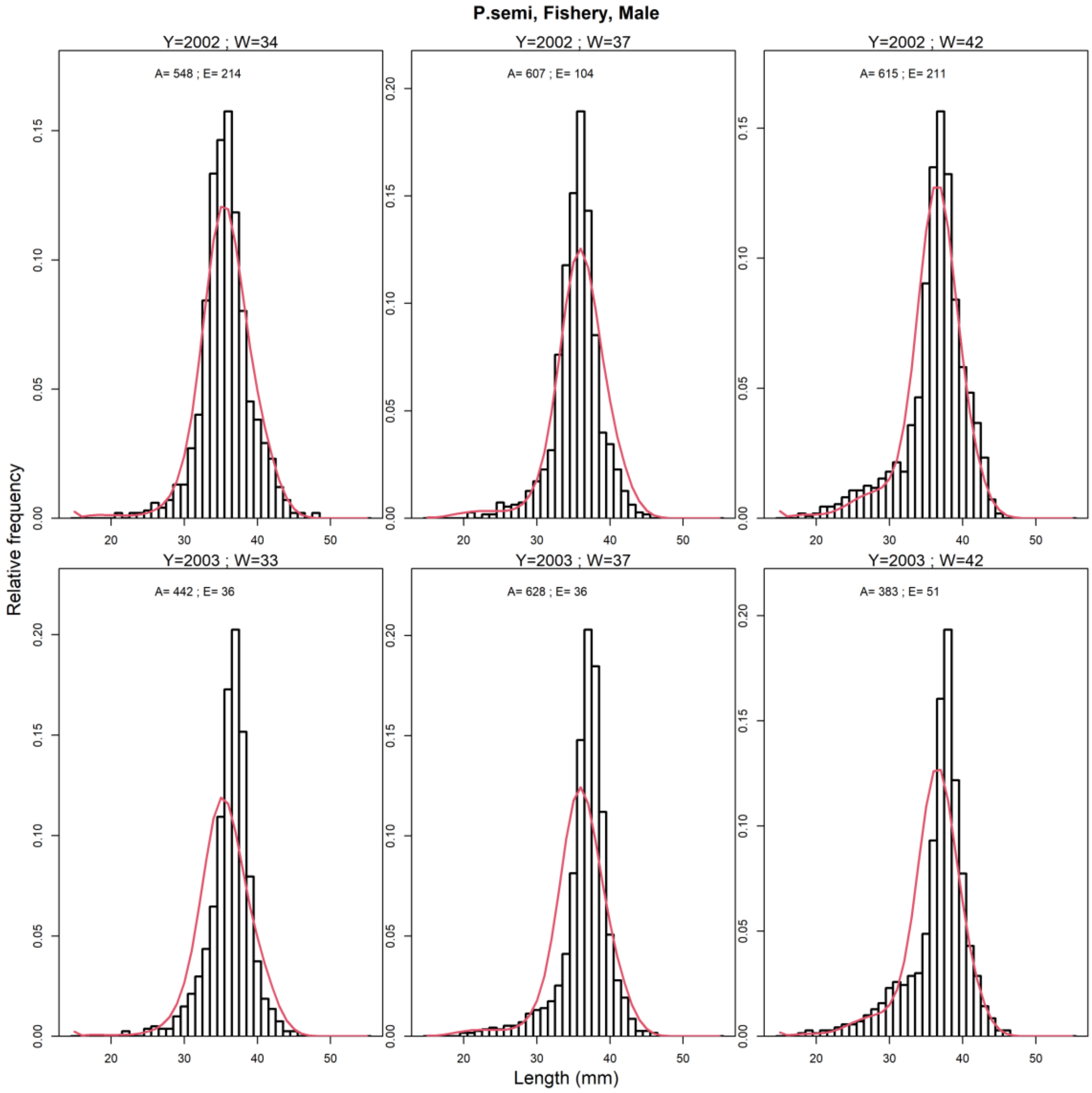
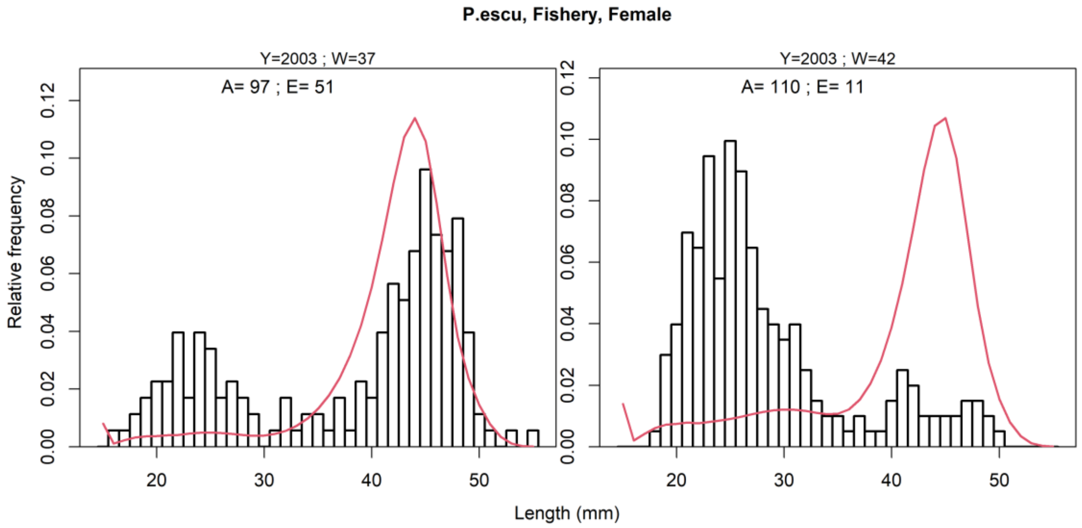

P.semi, Fishery, Male
Y=2002 ; W=34
A= 548 ; E= 214
Y=2002 ; W=37
A= 607 ; E= 104
Y=2002 ; W=42
A= 615 ; E= 211
Y=2003 ; W=33
A= 442 ; E= 36
Y=2003 ; W=37
A= 628 ; E= 36
Y=2003 ; W=42
A= 383 ; E= 51
Relative frequency
Length (mm)

Figure 23. Observed (histograms) and model-predicted (red lines) size-compositions for the fishery for Brown Tiger Prawns. a) female; b) male.

a)



b)

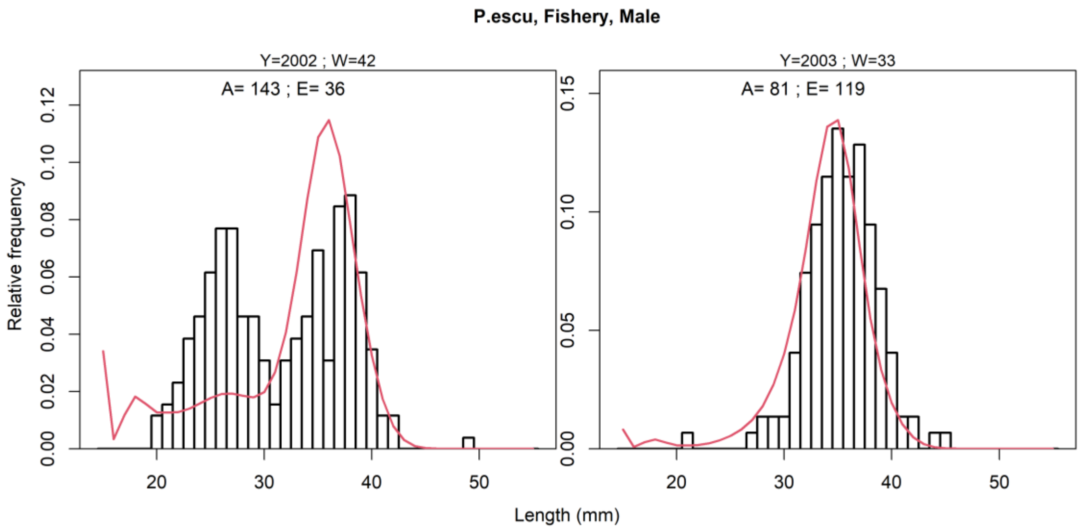
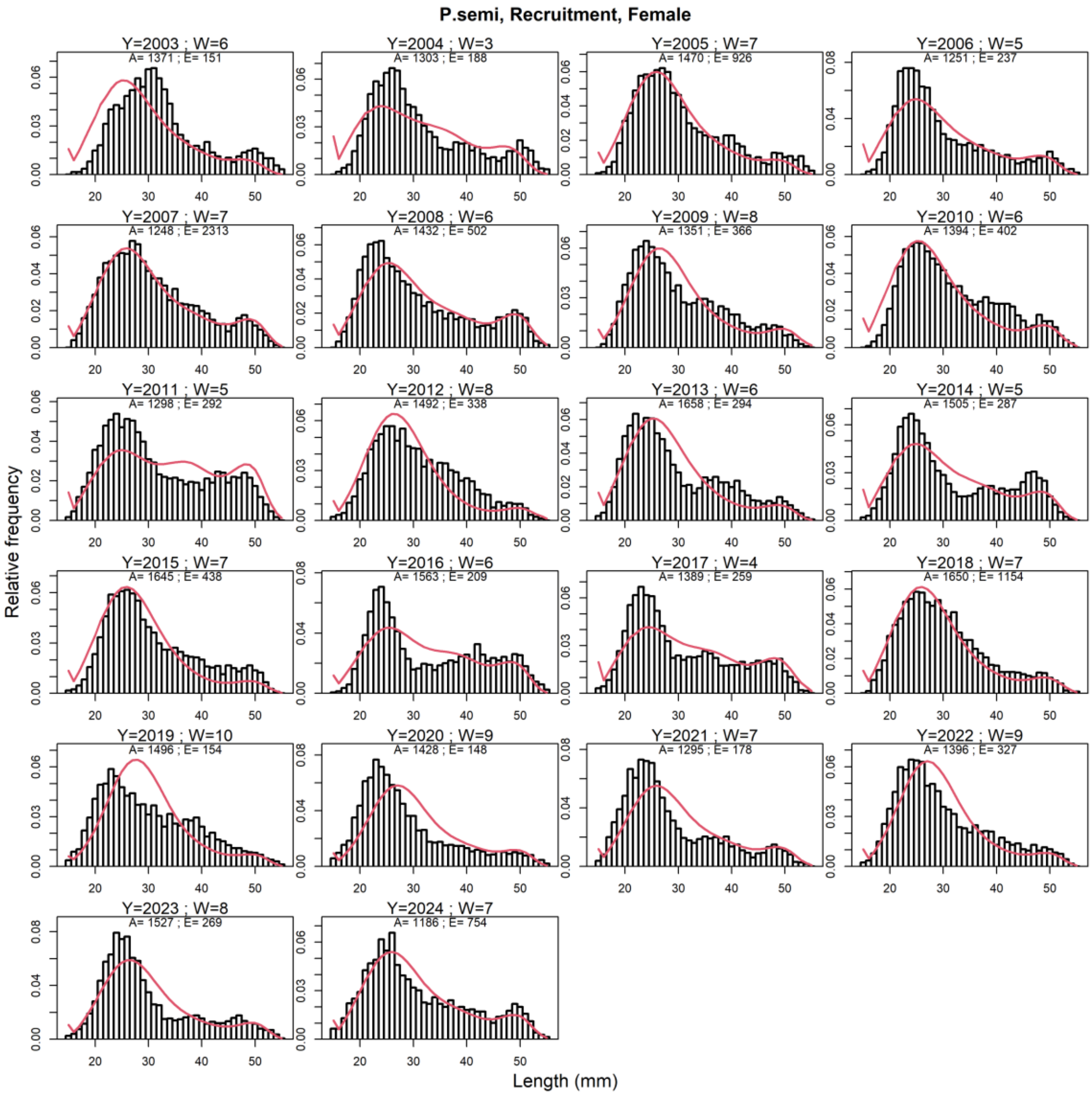


Figure 24. Observed (histograms) and model-predicted (red lines) size-compositions for the recruitment survey for Grooved Tiger Prawns**.** a) female; b) male

a)



b)

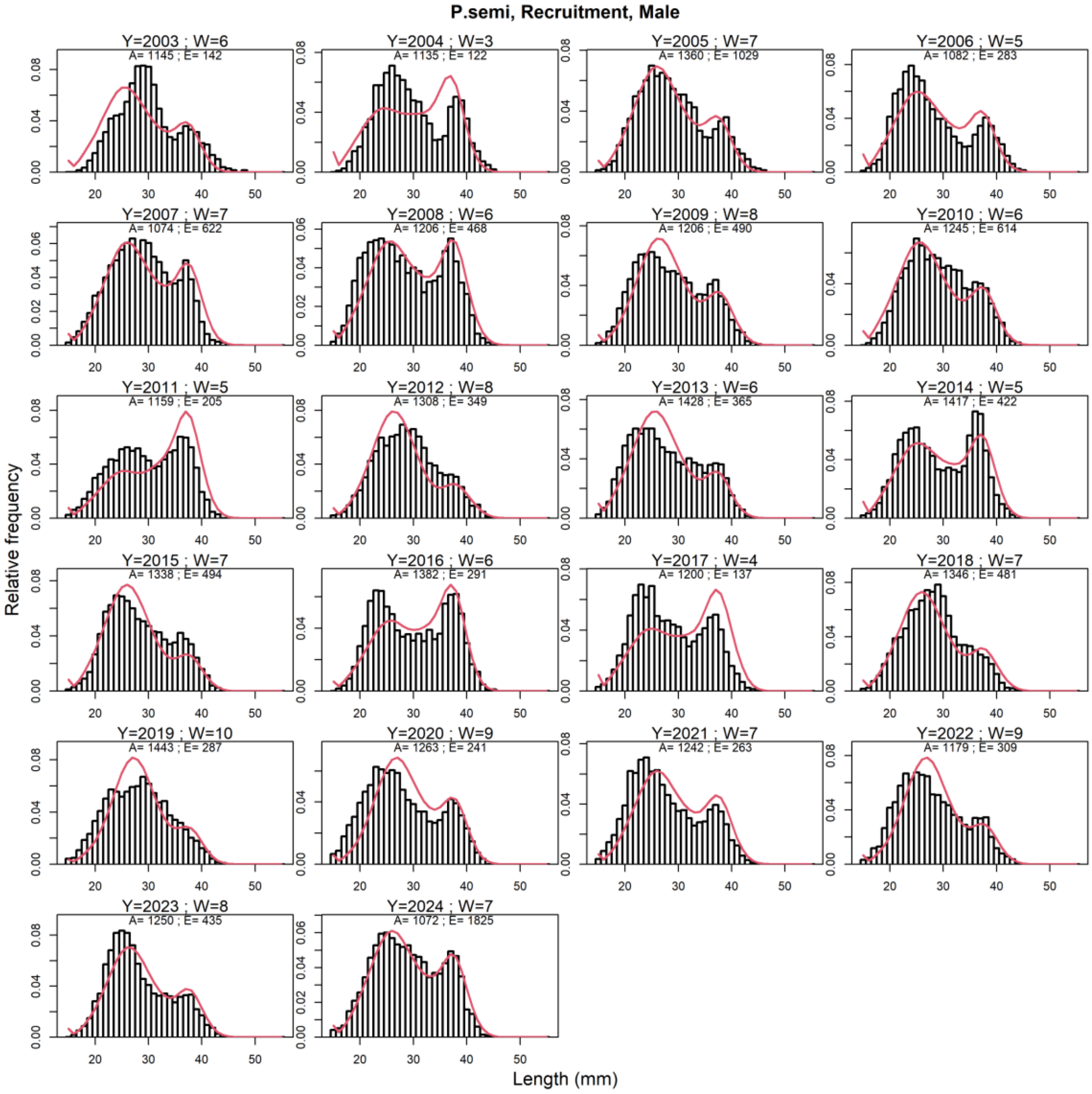
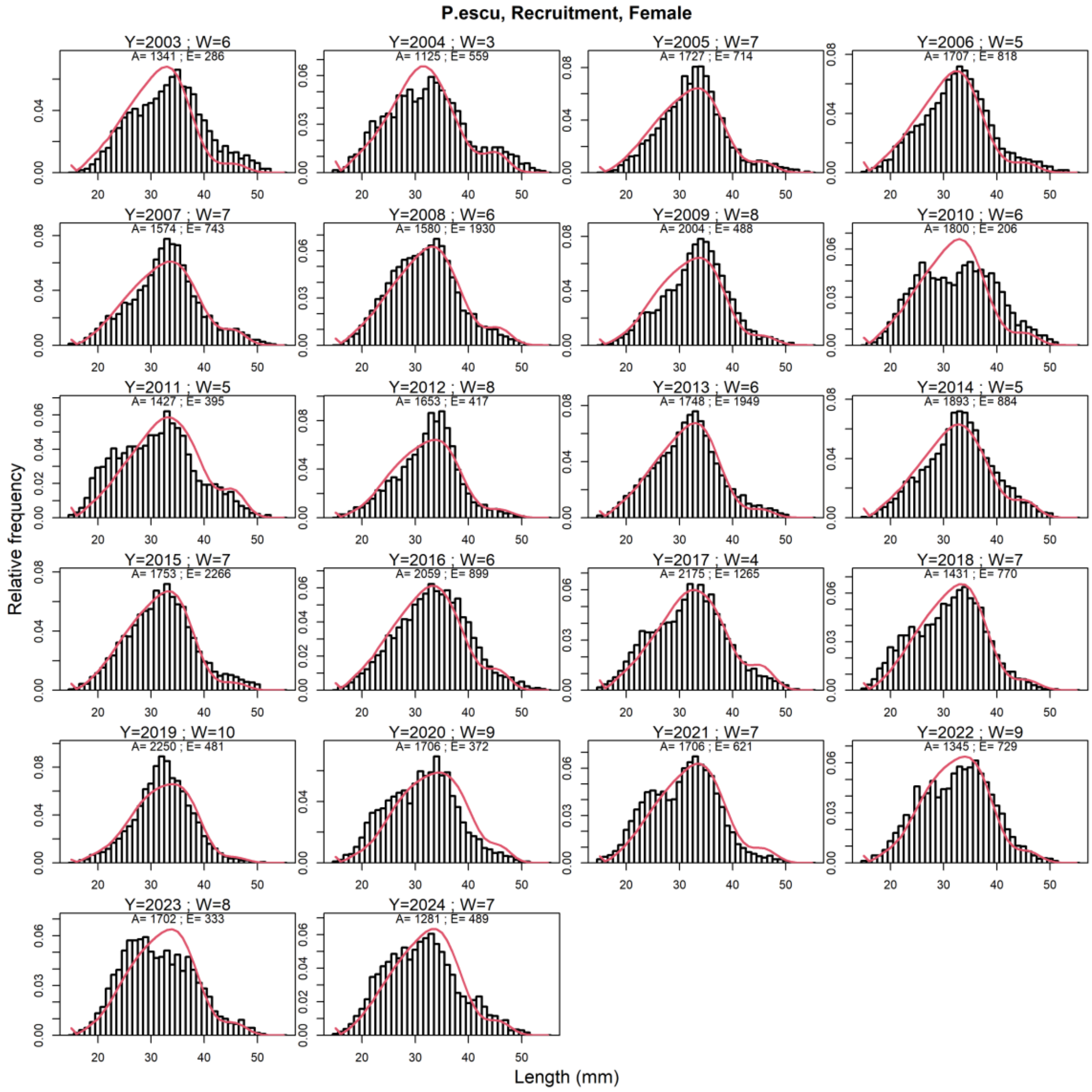

P.semi, Recruitment, Male
Y=2003 ; W=6
A= 1145 ; E= 142
Y=2004 ; W=3
A= 1135 ; E= 122
Y=2005 ; W=7
A= 1360 ; E= 1029
Y=2006 ; W=5
A= 1082 ; E= 283
Y=2007 ; W=7
A= 1074 ; E= 622
Y=2008 ; W=6
A= 1206 ; E= 468
Y=2009 ; W=8
A= 1206 ; E= 490
Y=2010 ; W=6
A= 1245 ; E= 614
Y=2011 ; W=5
A= 1159 ; E= 205
Y=2012 ; W=8
A= 1308 ; E= 349
Y=2013 ; W=6
A= 1428 ; E= 365
Y=2014 ; W=5
A= 1417 ; E= 422
Y=2015 ; W=7
A= 1338 ; E= 494
Y=2016 ; W=6
A= 1382 ; E= 291
Y=2017 ; W=4
A= 1200 ; E= 137
Y=2018 ; W=7
A= 1346 ; E= 481
Y=2019 ; W=10
A= 1443 ; E= 287
Y=2020 ; W=9
A= 1263 ; E= 241
Y=2021 ; W=7
A= 1242 ; E= 263
Y=2022 ; W=9
A= 1179 ; E= 309
Y=2023 ; W=8
A= 1250 ; E= 435
Y=2024 ; W=7
A= 1072 ; E= 1825
Relative frequency
Length (mm)

Figure 25. Observed (histograms) and model-predicted (red lines) size-compositions for the recruitment survey for Brown Tiger Prawns. a) female; b) male

a)



b)

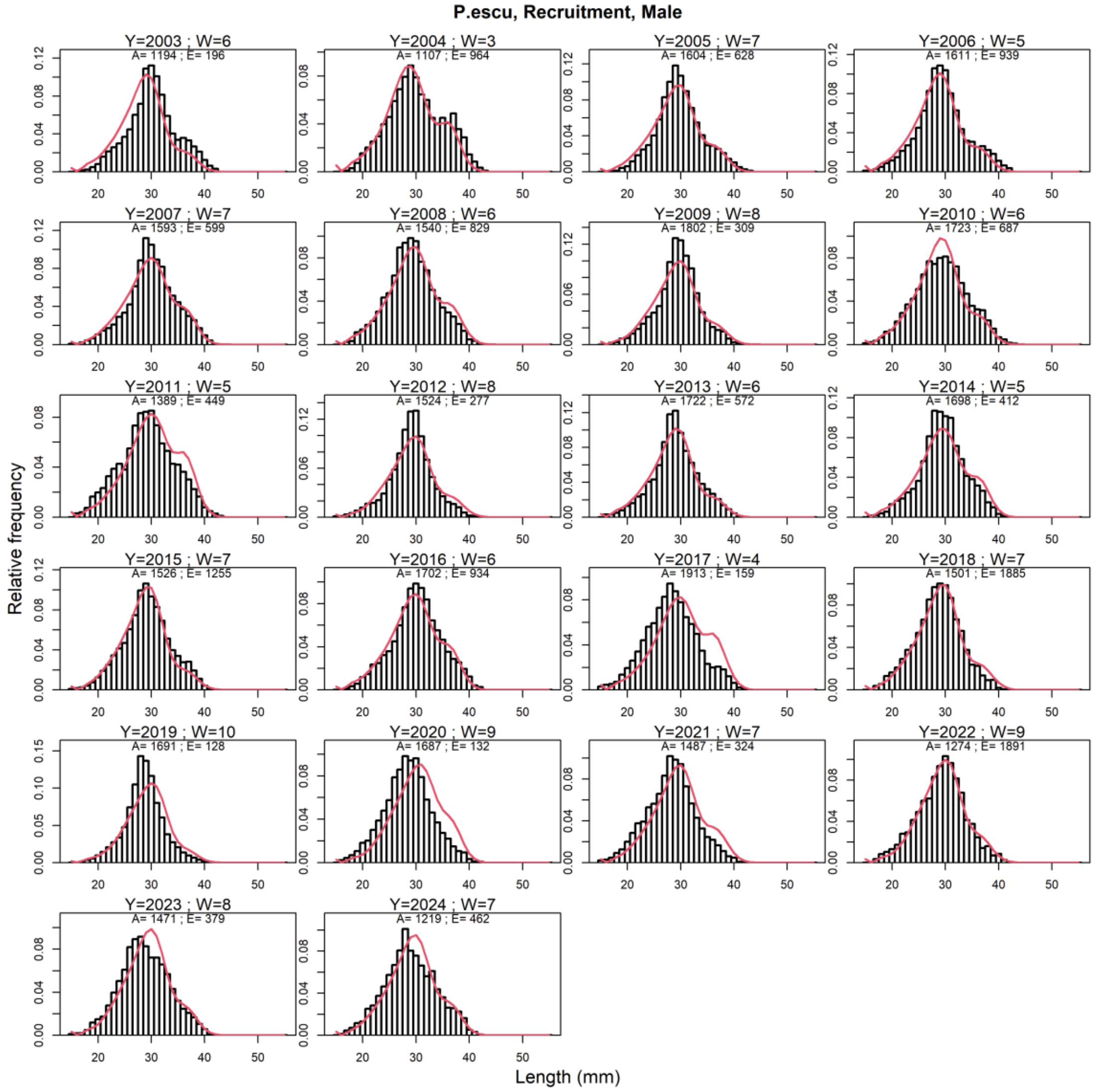
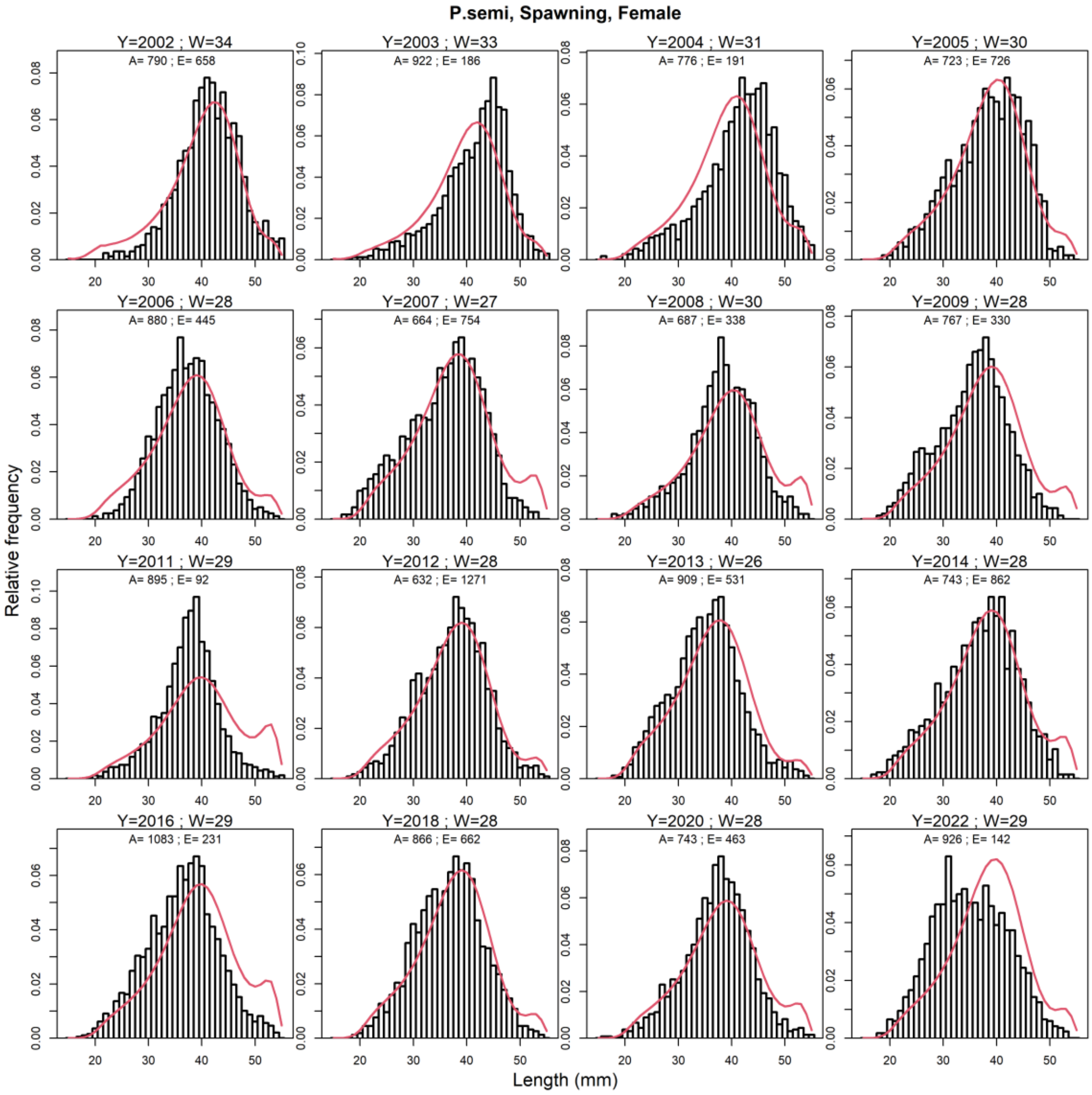

P.escu, Recruitment, Male
Y=2003 ; W=6
A= 1194 ; E= 196
Y=2004 ; W=3
A= 1107 ; E= 964
Y=2005 ; W=7
A= 1604 ; E= 628
Y=2006 ; W=5
A= 1611 ; E= 939
Y=2007 ; W=7
A= 1593 ; E= 599
Y=2008 ; W=6
A= 1540 ; E= 829
Y=2009 ; W=8
A= 1802 ; E= 309
Y=2010 ; W=6
A= 1723 ; E= 687
Y=2011 ; W=5
A= 1389 ; E= 449
Y=2012 ; W=8
A= 1524 ; E= 277
Y=2013 ; W=6
A= 1722 ; E= 572
Y=2014 ; W=5
A= 1698 ; E= 412
Y=2015 ; W=7
A= 1526 ; E= 1255
Y=2016 ; W=6
A= 1702 ; E= 934
Y=2017 ; W=4
A= 1913 ; E= 159
Y=2018 ; W=7
A= 1501 ; E= 1885
Y=2019 ; W=10
A= 1691 ; E= 128
Y=2020 ; W=9
A= 1687 ; E= 132
Y=2021 ; W=7
A= 1487 ; E= 324
Y=2022 ; W=9
A= 1274 ; E= 1891
Y=2023 ; W=8
A= 1471 ; E= 379
Y=2024 ; W=7
A= 1219 ; E= 462
Relative frequency
Length (mm)

Figure 26. Observed (histograms) and model-predicted (red lines) size-compositions for the spawning survey for Grooved Tiger Prawns. a) female; b) male

a)



b)

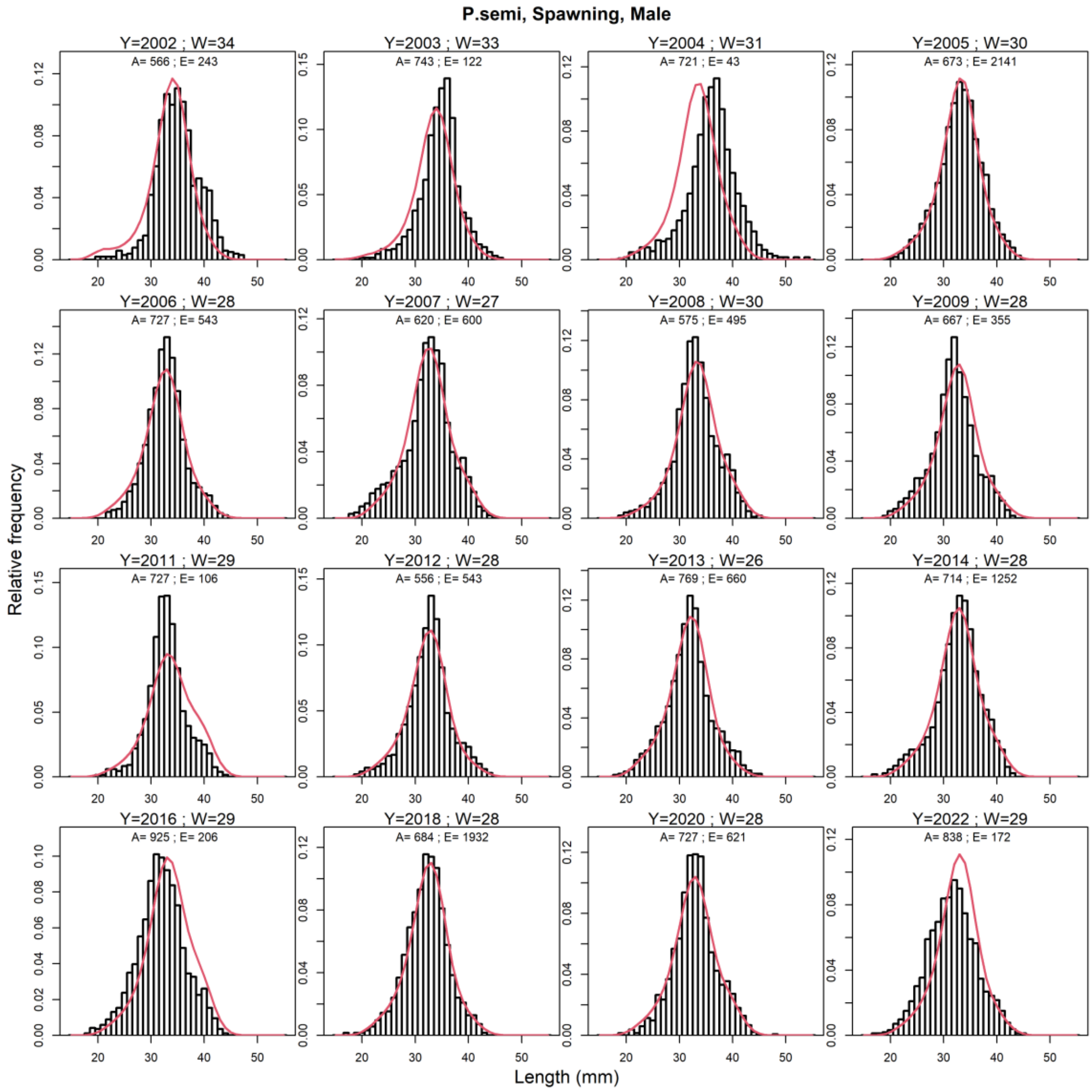
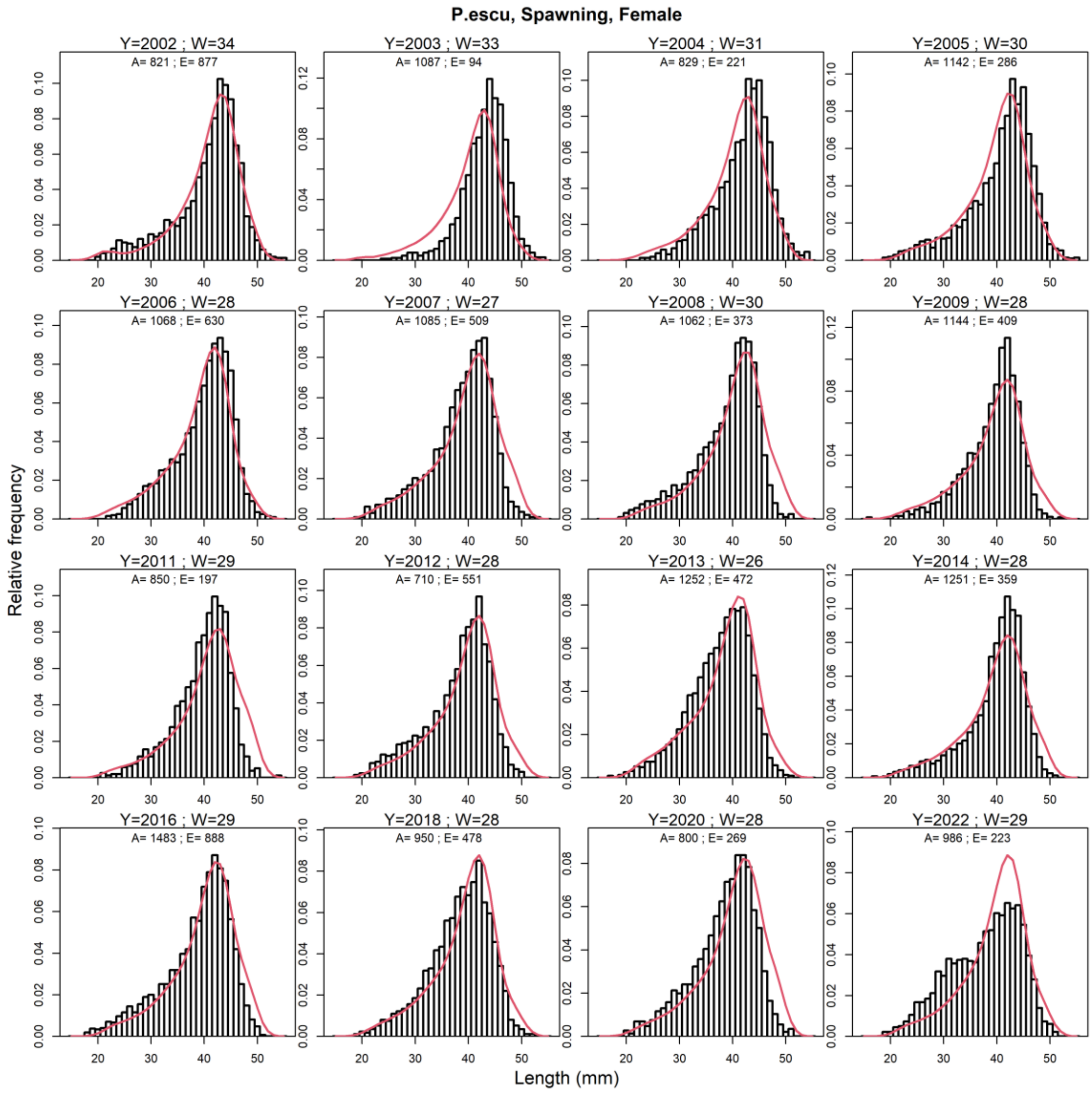

P.semi, Spawning, Male
Y=2002 ; W=34
A= 566 ; E= 243
Y=2003 ; W=33
A= 743 ; E= 122
Y=2004 ; W=31
A= 721 ; E= 43
Y=2005 ; W=30
A= 673 ; E= 2141
Y=2006 ; W=28
A= 727 ; E= 543
Y=2007 ; W=27
A= 620 ; E= 600
Y=2008 ; W=30
A= 575 ; E= 495
Y=2009 ; W=28
A= 667 ; E= 355
Y=2011 ; W=29
A= 727 ; E= 106
Y=2012 ; W=28
A= 556 ; E= 543
Y=2013 ; W=26
A= 769 ; E= 660
Y=2014 ; W=28
A= 714 ; E= 1252
Y=2016 ; W=29
A= 925 ; E= 206
Y=2018 ; W=28
A= 684 ; E= 1932
Y=2020 ; W=28
A= 727 ; E= 621
Y=2022 ; W=29
A= 838 ; E= 172
Relative frequency
Length (mm)

Figure 27. Observed (histograms) and model-predicted (red lines) size-compositions for the spawning survey for Brown Tiger Prawns. a) female; b) male

a)



b)

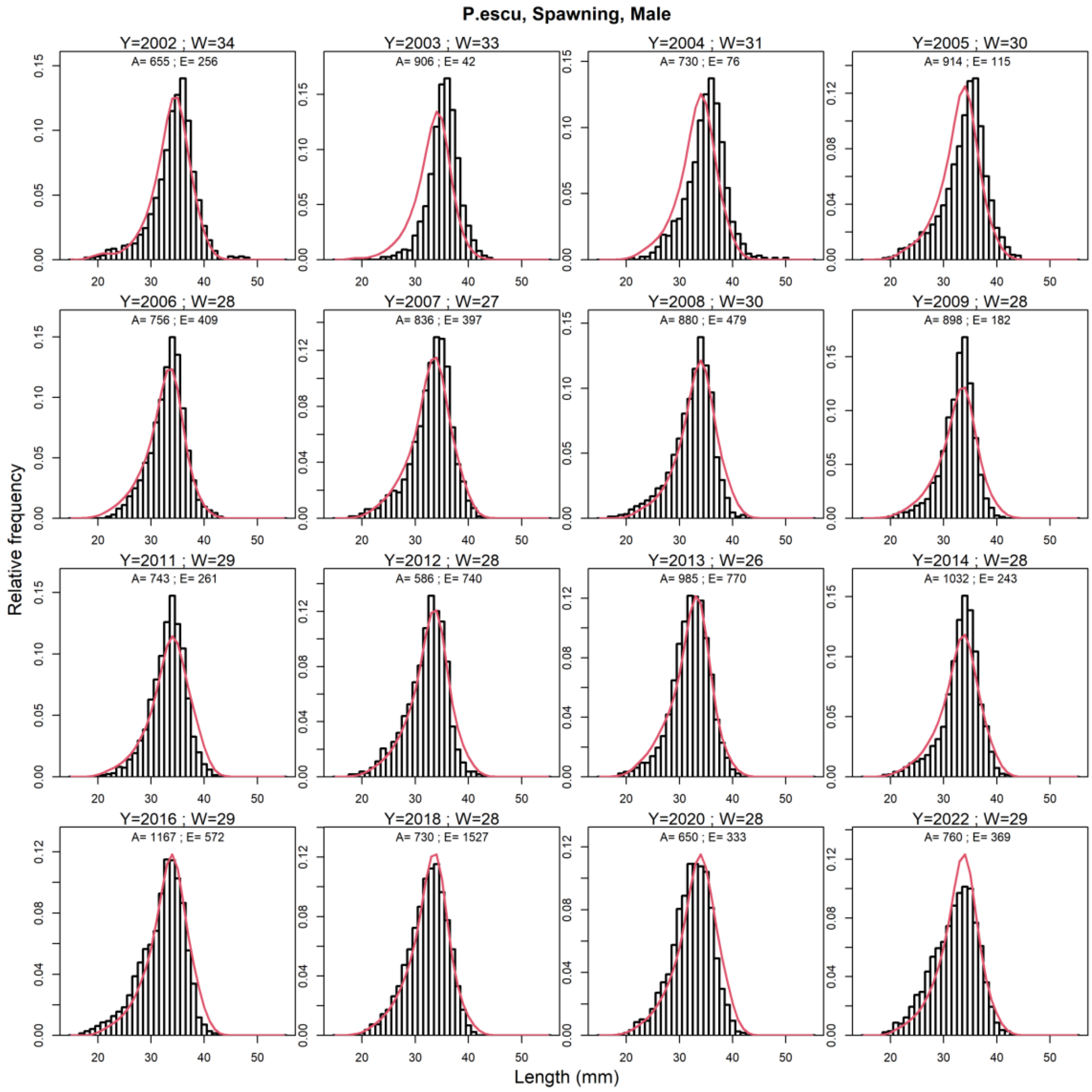

P.escu, Spawning, Male
Y=2002 ; W=34
A= 655 ; E= 256
Y=2003 ; W=33
A= 906 ; E= 42
Y=2004 ; W=31
A= 730 ; E= 76
Y=2005 ; W=30
A= 914 ; E= 115
Y=2006 ; W=28
A= 756 ; E= 409
Y=2007 ; W=27
A= 836 ; E= 397
Y=2008 ; W=30
A= 880 ; E= 479
Y=2009 ; W=28
A= 898 ; E= 182
Y=2011 ; W=29
A= 743 ; E= 261
Y=2012 ; W=28
A= 586 ; E= 740
Y=2013 ; W=26
A= 985 ; E= 770
Y=2014 ; W=28
A= 1032 ; E= 243
Y=2016 ; W=29
A= 1167 ; E= 572
Y=2018 ; W=28
A= 730 ; E= 1527
Y=2020 ; W=28
A= 650 ; E= 333
Y=2022 ; W=29
A= 760 ; E= 369
Relative frequency
Length (mm)

Figure 28. Observed (histograms) and model-predicted (red lines) size-compositions combined over time for Grooved Tiger Prawns in general, regarding spawning, and regarding recruitment for females (a, c, and e, respectively) and males (b, d, and f, respectively).

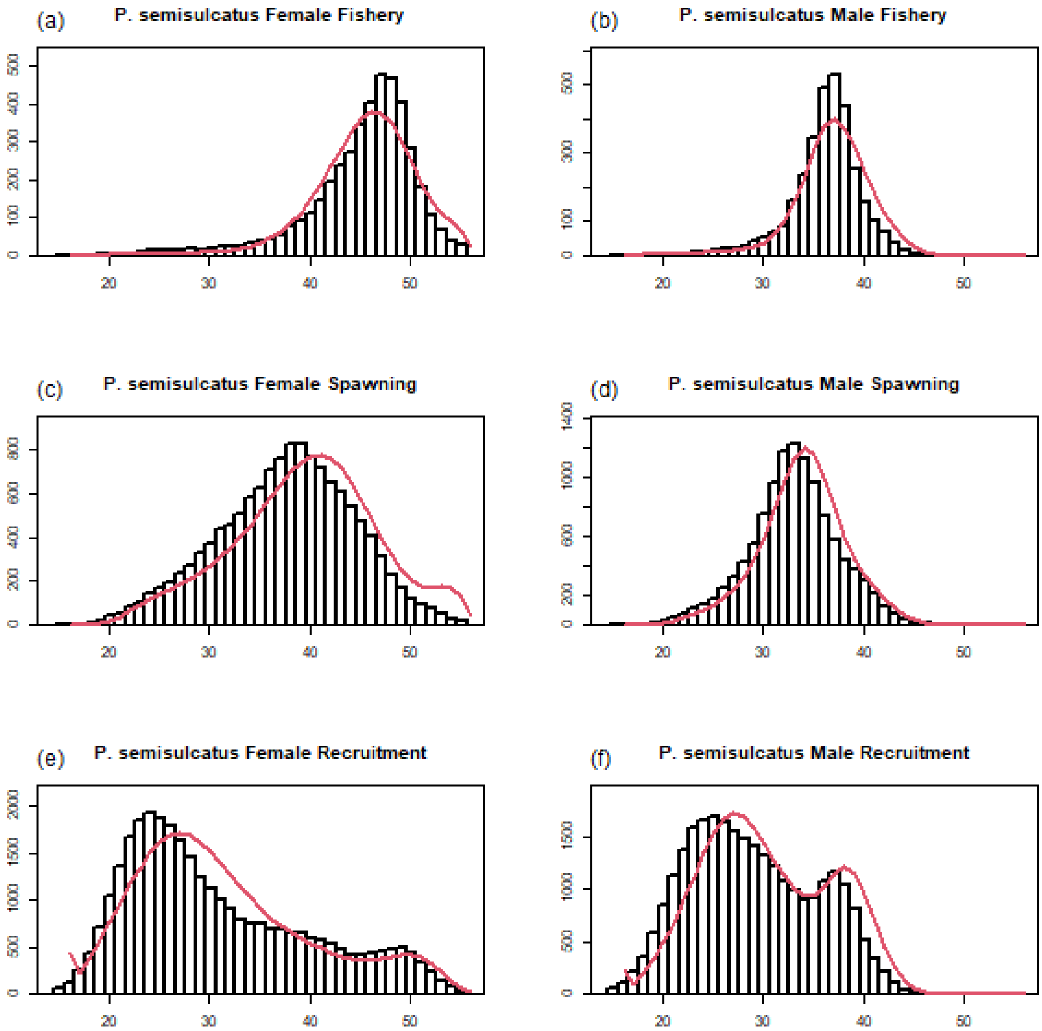


Figure 29. Observed (histograms) and model-predicted (red lines) size-compositions combined over time for Brown Tiger Prawns in general, regarding spawning, and regarding recruitment for females (a, c, and e, respectively) and males (b, d, and f, respectively).

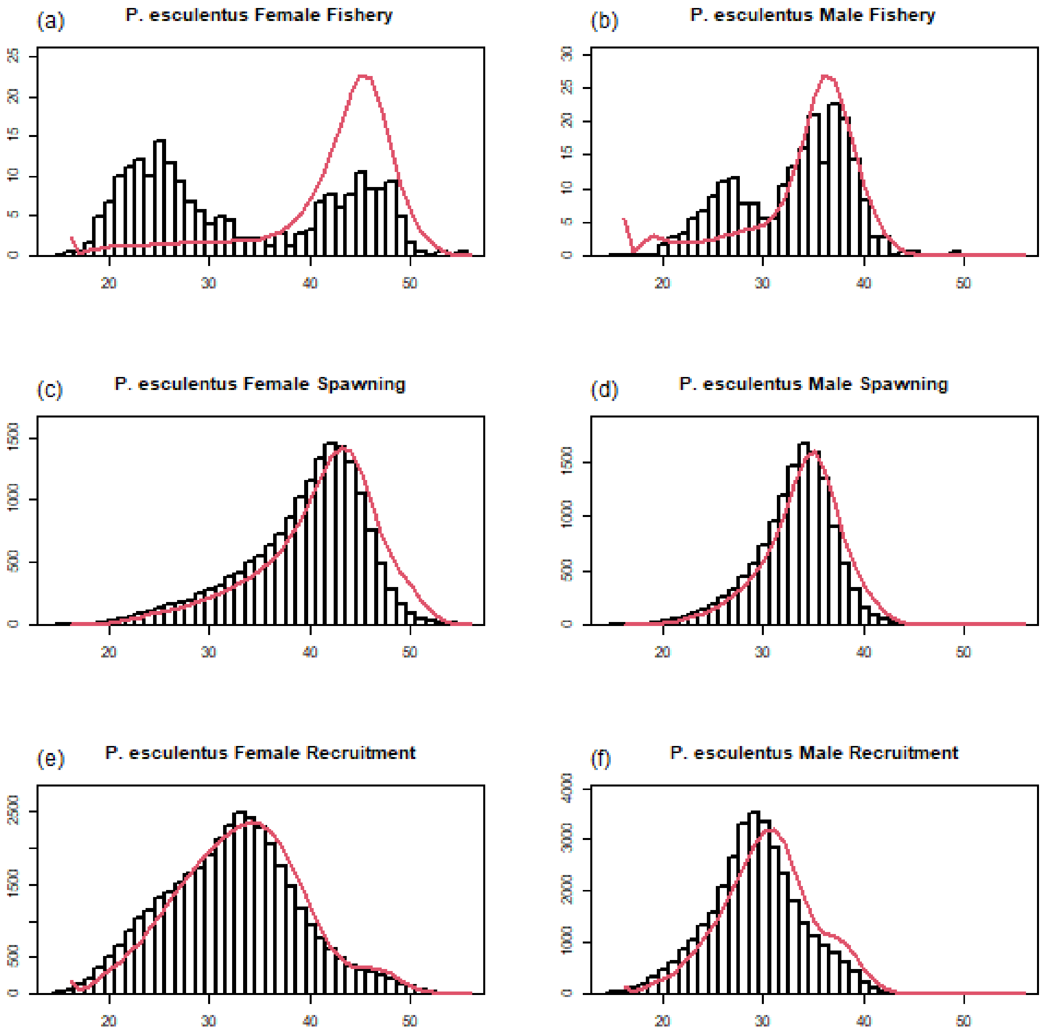
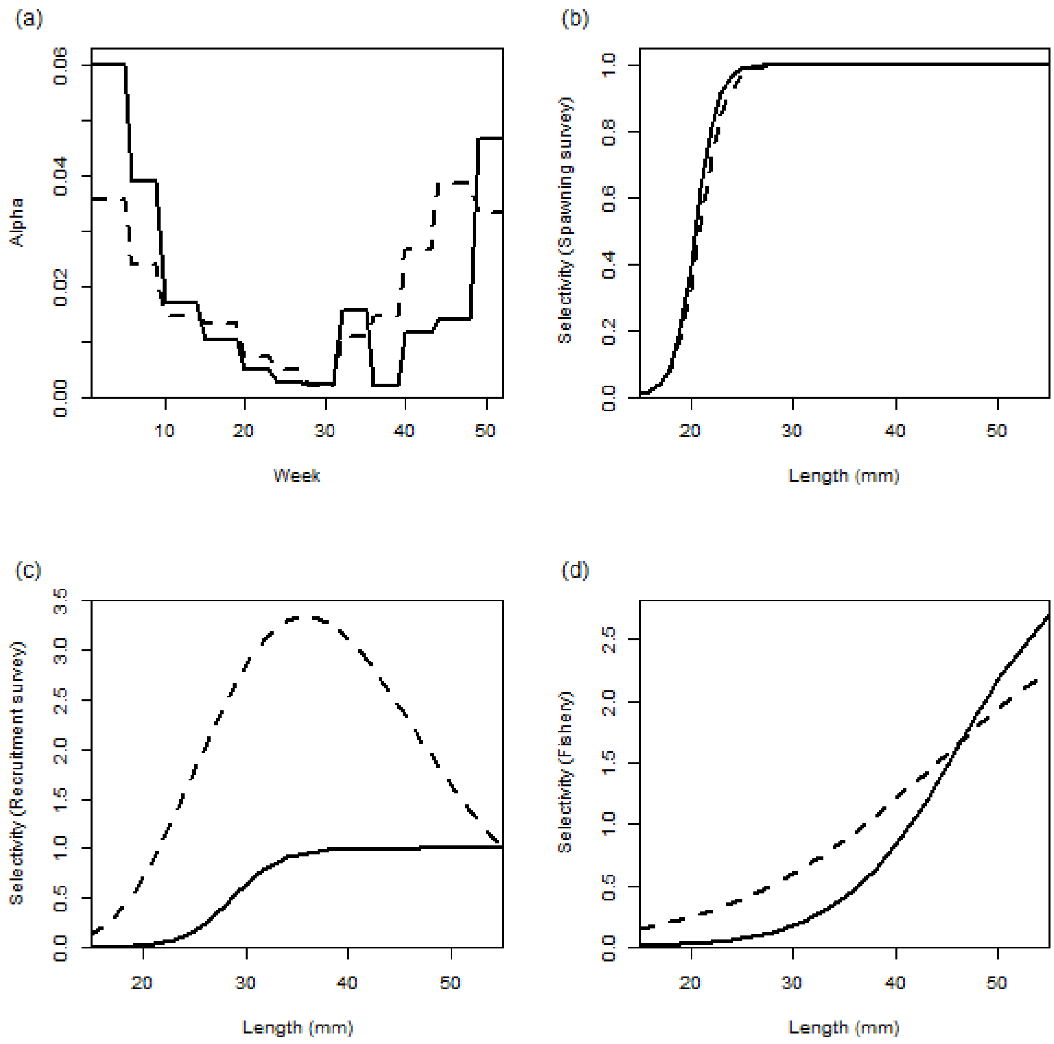


Figure 30. Estimates of biological and fishery parameters for the Base Case size-structured population model (Solid lines - Grooved Tiger Prawns; dashed lines for Brown Tiger Prawns).

(a) monthly recruitment pattern, (b) selectivity to the spawning survey, (c) selectivity to the recruitment survey, and (d) selectivity to the fishery.



5.4 Bio-Economic assessment

The current prawn prices and fuel prices provided by Prof. Tom Kompas are shown in Table 8. Future average prawn prices (Table 8a) were set to be same as that of 2023-2024 and future fuel unit effort costs were set as a constant based on the fuel price provided NPFI in May 2024 (NFRAG meeting, Feb 2024). The Tiger Prawn price ratio split across the different size grades is based on commercial catch information provided by Austral Fisheries Pty Ltd. in February 2014.

In this section we refer to the cost data provided in Table 8b. The cost of the labour parameter is the crew share of revenue, which is a proportion of total revenue. The “other variable costs” represent packaging, freight and other marketing related costs (including levies). Repairs and maintenance costs (which include gear costs) are estimated on a cost per day basis. Fuel and grease costs are also estimated on a cost per day basis. Annual vessel costs include administration, licence costs, insurance and other annual costs, but exclude interest and rent payments.

The capital costs estimate is provided in Table 8b. As with the annual fixed costs, a share of total capital costs (for the whole NPF) was allocated to the Tiger Prawn fishery, based on its share of total revenue (i.e. considering also the revenue earned from the banana prawn fishery).

The opportunity cost of capital (which is the “normal” expected rate of return on investment in the fishery, and is also equivalent to the discount rate used in the analysis) and the economic depreciation rate (which measures how much capital depreciates each year when fishing, after allowing for repairs and maintenance) are unchanged from the previous assessments. Table 8c provides the price and fuel cost indices used in the projections.

Results of the Base Case bio-economic assessment are provided in Table 1Table Appendix A 1. Values of relevant management measures and parameter estimates for the three species for the Base Case (SSB - “low” fishing power, the average of last two years’ effort patterns). and Figure 5. Relative to Maximum Economic Yield (MEY), the Base Case Grooved Tiger Prawn abundance estimate was S_{2023}/S_{MEY} = 0.72. The S_{2023}/S_{MEY} estimates ranged between 0.68 - 0.76 in all the scenarios tested. Similarly, the Brown Tiger Prawn Base Case estimate was S_{2023}/S_{MEY} = 0.57 and ranged between 0.51 - 0.62 in all scenarios. For Blue Endeavour Prawns the Base Case estimate was S_{2023}/S_{MEY} = 1.18 and ranged between 0.56 - 1.18 in all scenarios tested. In the four species scenario, the estimate for Red Endeavour Prawns was S_{2023}/S_{MEY} = 1.22.

Model projections indicate that the Grooved Tiger Prawn stocks will achieve the current target reference point, S_{MEY}, by 2031. However, Brown Tiger Prawn's current stock status is lower than that of Grooved Tiger Prawn and will, therefore, require a longer period to achieve S_{MEY} (Figure 5c).

In 2023, targeted effort relative to MSY on Grooved Tiger Prawns was $E_{2023}/E_{MSY} = 0.43$ and Brown Tiger Prawns was marginally higher, $E_{2023}/E_{MSY} = 0.51$; both values suggest that the current effort is substantially lower than that required to achieve maximum sustainable yield. As Blue Endeavour Prawns and Red Endeavour Prawns are treated as a byproduct (i.e., captured when effort is targeted at Tiger Prawns), this indicator is not applicable for these two species. The 2024 catch projections indicate an expected decrease in Grooved Tiger Prawn catches compared to 2023, from 921 tons to 675 tons. In contrast, projected catches for Brown Tiger Prawns are expected to increase marginally in 2024 compared to 2023, from 321 tons to 361 tons. These catch projections are dependent on the associated species-specific effort allocation (see section 3.3).

The NPF Tiger Prawn fishery is projected to be run at a financial deficit given the current estimates of target species' stock status and, more importantly, the economic data and assumptions on future costs and prawn prices (Table 1, Table Appendix A 2). The major economic drivers are the significant increase in the fuel cost, as well as the repair and maintenance costs (Table 8b).

Notably, the 2023 Base Case S_{MEY}/S_{MSY} values for Grooved and Brown Tiger Prawns are 1.50 and 1.43, respectively, which are substantially higher than the conventionally accepted proxy of $S_{MEY}/S_{MSY} = 1.2$. This suggests that a high biomass is required to maximise economic yield. Simply put, given the current economic climate (i.e., the relatively high cost of fishing) high catch rates are required maximise economic yield. However, the elevated catch rates required to reach MEY are only possible when prawn biomass is high; higher than current stock status. Given the assumption of constant price and cost projections, substantial growth in the biomass (S/S_{MSY}) will be required for both species (see Figure 1 and Figure 2) to shift the current S_{2030}/S_{MEY} estimates of 0.99 and 0.96 for Grooved and Brown Tiger Prawn, respectively, toward the target reference point of $S_{2030}/S_{MEY} = 1$ by 2030. For Blue Endeavour Prawns (Base Case) and Red Endeavour Prawns (four species sensitivity test), the S_{MEY}/S_{MSY} ratios are 0.99 and 0.88, respectively. Importantly, the costs for Blue Endeavour Prawns and Red Endeavour Prawns, caught as a byproduct, are limited to those associated with catch (e.g., packaging and freight) but not effort (e.g., fuel).

Table 8. The Base Case prices (a) and the cost variables (b) used in the current assessment (this report) as well as (c) the future (up to 2026) predicted price and fuel cost change indices.

(a) Prices (A$/kg)[2]

Species Group	All sizes	< 40 mm	40-45 mm	45-50 mm	50-55 mm	> 55 mm
Tiger	27.73	21.90	28.56	31.46	37.13	43.80
Endeavour	10.66					

(b) Cost variables[3]

Parameter	2023 Values	2021 Values used in the last assessment
Cost of labour multiplier, c_L	0.276	0.24
Unit cost of other costs, c_M	0.887 (A$ / kg)	1.70 (A$ / kg)
Unit cost of repairs and maintenance, c_K	644 (A$ / day)	504 (A$ / day)
Base unit cost of fuel and grease, c_F	4,760 (A$ / day)	2,330 (A$ / day)
Annual vessel costs, W_y	290,690 (A$ / vessel)	310,330 (A$ / vessel)
Opportunity cost of capital, o	0.05	0.05
Economic depreciation rate, d	0.02	0.02
Average value of capital, K_y	544,686 (A$ / vessel)	518,941 (A$ / vessel)
2024 Base unit cost of fuel and grease, c_F	4,720 (A$ / day)	

(c) Prawn prices and fuel costs index[4]

Year	Prawn prices index (%)	Fuel costs index (%)
2024	100	100
2025	100	100
2026	100	100
2027	100	100
2028	100	100
2029	100	100
2030	100	100

It should be noted when looking at the estimated effort projections (Figure 31), that annual effort will fluctuate in the first few years and then to stabilize as stock sizes approach the target levels, (S_{2023}/S_{MEY} is 0.72 and 0.57 for Grooved and Brown Tiger Prawns

[2] average prices provided by Tom Kompas and category prices are updated using information by David Carter;

[3] provided by Sean Pascoe and Tom Kompas;

[4] provided by Tom Kompas;

respectively), and reach equilibrium effort during the last few years of the projection (Figure 31). Figure 31 shows the predicted future catches, S_Y/S_{MEY}, and profit for the Base Case, along with the effort trends (as discussed).

Figure 31. The key bio-economic model results (indicators) for the Base Case

(a) Tiger Prawn effort (standardised boat days), (b) prawn catch (tonnes), (c) S_Y/S_{MSY}, and (d) total projected profit (millions of Australian dollars) for the Base Case assessment and projection settings.

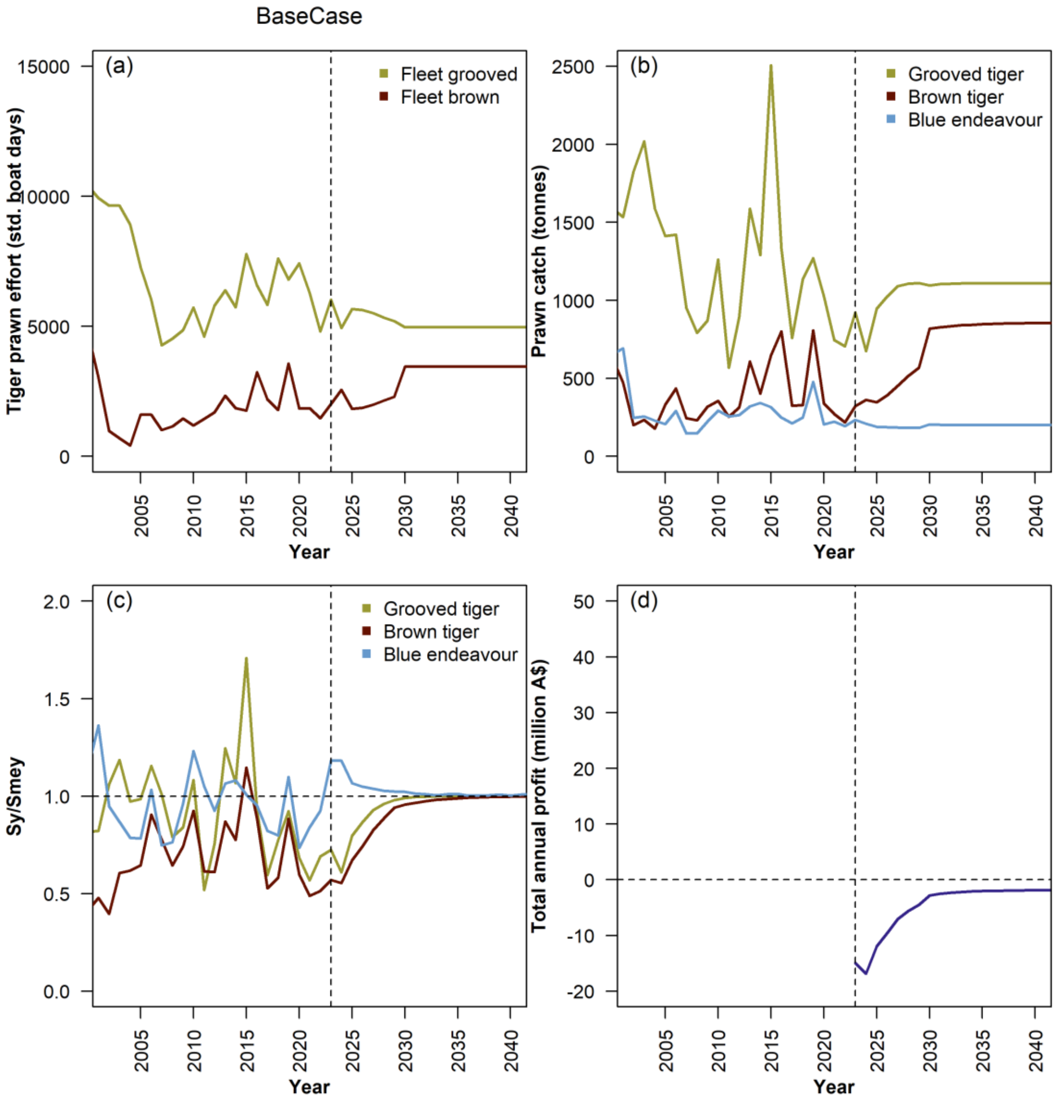
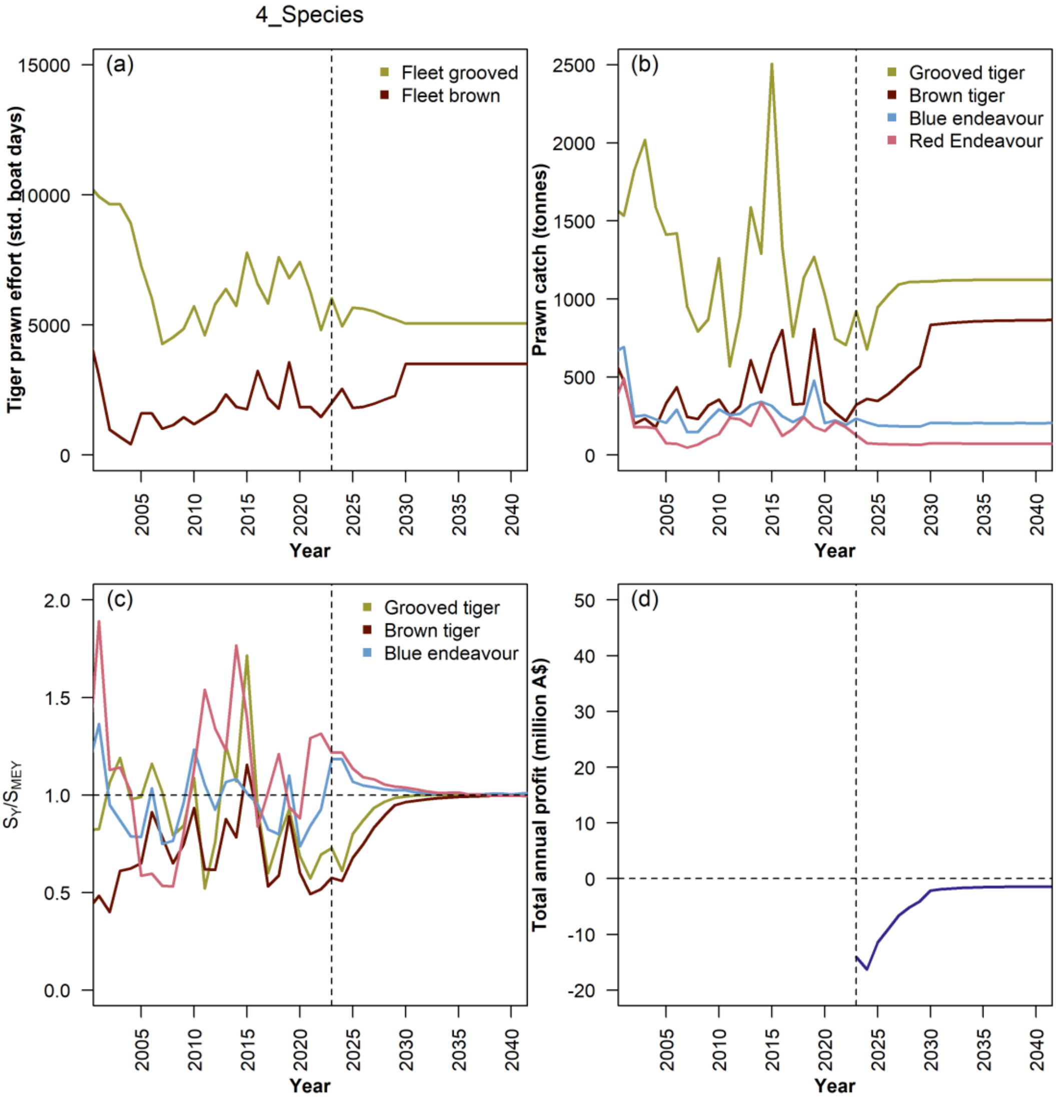


Figure 32. The key bio-economic model results (indicators) for the four-species models

(a) Tiger Prawn effort (standardised boat days), (b) prawn catch (tonnes), (c) S_Y/S_{MSY}, and (d) total projected profit (millions of Australian dollars) for the Base Case assessment and projection settings.



Recommended Total Allowable Effort (TAE)

The Tiger Prawn Base Case results indicate that given the RAG-approved distribution of relative fishing effort pattern for projections, the 2024 fishing effort levels required to achieve MEY are 2645 boat days for Grooved Tiger Prawns and 1368 boat days for Brown Tiger Prawns; a total of 4013 boat days. This is a 9.4% decrease on total actual effort in 2023, which is equivalent to a 31% gear size decrease (Table 2). The optimal 2024 fishing effort estimates derived from the various sensitivity tests ranged between 1536 - 4430 boat days in total, noting that the lowest value resulted from the scenario where no MET was applied. The 2025 projected total fishing effort remains 4013 boat days, however effort targeted at

Grooved Tiger Prawns increases to 3036 boat days, while a reciprocal decrease is observed for Brown Tiger Prawns to 977 boat days.

7 Benefits and Adoption

The assessment provided estimates of stock status for Grooved and Brown Tiger, Blue Endeavour and Redleg Banana Prawns. The outcome provided was a demonstration of the sustainability of the NPF target species, and estimated levels of sustainable fishing effort for each Tiger Prawn species. Additionally, the economic analyses evaluated the degree to which the fisheries for these species were operating near economic optimum. Under current fishery economic condition and target species stock status, the assessment projected negative economic profit from 2024 onward. In accordance with the NPF Harvest Strategy the predictive component of the models supported recommendations for:

1. The TAE for the Tiger Prawn fishery (including Endeavour prawns; 2024 and 2025) (full assessment in 2024).
2. The TAE for Redleg Banana Prawns (2024) (published as a separate report).
3. The estimation of trigger catch rate limits for the White/Common Banana Prawn fishery for 2024 (see NPRAG minutes for the set trigger limit levels).

As the primary clients of this work were the management group of the Northern Prawn fishery (AFMA, NORMAC, NPRAG and NPFI), principal methods and results were communicated via the provision of progress reports to meetings of these groups. In addition, the various stakeholders provided feedback on the assessment project outputs which were incorporated to improve model outcomes. Presentations of all the work in this project were provided at all the NPRAG meetings (and many of the NORMAC meetings, as well as NPFI meetings) during the time frame of this project. Meeting minutes provide a public record of project outcomes and the recommendations for the TAE for each year that were endorsed by the NPRAG and NORMAC. The endorsed recommendations were sent to the AFMA Commission.

8 Further Development & Planned Outcomes

This project is in its last major phase of the three-year NPF Assessment project commenced in October 2021 (2021-2024). This project has not only achieved and delivered on the set of objectives originally outlined, but also developed and improved the NPF assessments under new and different circumstances and challenges. Some of the notable developments include implementing an updated Biomass Dynamic model for Endeavour Prawns, implementing the updated species-splitting model, developing a new Minimum Effort Threshold (MET), reviewing the Fishing Power model, and interrogating the influence of economic information. Given the critical importance of the NPF to the nation as a key Commonwealth fishery, its ongoing assessment (biological sustainability) must be maintained along with the maintenance of the key objective of maximising economic yield. Future research priorities should focus on the understanding and inclusion of climate change in NPF assessments and the development of adaptive harvest strategies. In this regard, progress has already been made for the Redleg Banana Prawn fishery (see Blamey et al., 2022) and there is ongoing work into climate change influences on Tiger prawn productivity under a current FRDC project (FRDC 2023-062). Despite this NPF Stock Assessment project reported here nearing its end, this research is expected to continue under a new three-year project commencing in November 2024 (2024-2027). The project co-PIs will maintain a close association with the NPF and continue to attend NPRAG and NORMAC meeting and provides ongoing project updates.

9 Conclusion and Recommendations

Developed and much improved over the last 30 years, the Tiger Prawn assessment outlined in this report has provided a quantitative measure of the stock status of four short-lived, highly-fecund prawn species that, without rigorous data inputs and analyses, would be difficult to manage sustainably. Each of the prawn species have highly variable populations, subject to annual tropical-extreme, monsoon-pulsed environmental drivers and on-going harvest pressure. The assessment is critical to the NPF Harvest Strategy for several reasons. The Harvest Strategy mandated that an assessment will be conducted biennially. In addition, the assessment provided key metrics for input into management decision making. The Harvest Strategy accounts for the large interannual variability of recruitment by deploying a pivotal decision rule that uses a 5-year moving average of S_{Y}/S_{MSY} to ensure that management action is taken prior if the value falls below 50%. The ratio S_{Y}/S_{MSY} was an output of the assessment, as were other metrics. The 5-year moving average targeted recruitment variation that, for each of the Tiger and Endeavour Prawn species, has been identified in Australian tropical fisheries.

The 2024 Tiger Prawn assessment results indicate that all prawn species are above their limit reference points and, therefore, not considered to be overfished.

The Tiger Prawn Base Case results indicate that the 2024 fishing effort levels required to achieve MEY are 2645 boat days for Grooved Tiger Prawns and 1368 boat days for Brown Tiger Prawns; a total of 4013 boat days. This is a 9.4% decrease on total actual effort in 2023, which equates to a 31% gear size decrease. The 2025 projected total fishing effort remains 4013 boat days, however effort targeted at Grooved Tiger Prawns increases to 3036 boat days, while a reciprocal decrease is observed for Brown Tiger Prawns to 977 boat days.

The Tiger Prawn assessment provided projected efforts from various scenarios to help the NPRAG to make informed decisions with respect to setting the 2024 and 2025 TAEs. By this measure, the assessment supported sustainable management of the NPF via the Harvest Strategy.

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Appendices

Appendix A. Summary tables for base case and sensitivity tests

Table Appendix A 1. Values of relevant management measures and parameter estimates for the three species for the Base Case (SSB - “low” fishing power, the average of last two years’ effort patterns). E_{MSY} is the effort level (expressed in terms of 2023 boat days) at which MSY is achieved and S_{MSY} is the spawner stock size at which the (deterministic) MSY is achieved. **mav = moving average**

Name	Grooved Tiger Prawns	Brown Tiger Prawns	Blue Endeavour Prawns
Steepness	0.43	0.311	NA
Catch 2024 (t)	675	361	209
Observed C2023 (t)	921	321	233
MSY (t)	1632	982	435
MEY (t)	1109	856	199
S_{MEY}/S_{MSY}	1.50	1.43	0.99
S_{2023}/S_0	0.55	0.41	1.01
S_{2023}/S_{MSY}	1.08	0.81	1.17
S_{2023}/S_{MEY}	0.72	0.57	1.18
5-year mav($S_{2019\text{-}2023}/S_{MSY}$)	1.07	0.87	0.95
S_{2030}/S_{MEY}	0.99	0.96	1.02
Observed nominal E_{2023} (d)	3314	1116	NA
Estimated nominal E_{2024} (d)	2645	1368	NA
Estimated nominal E_{2025} (d)	3036	977	NA
E_{MSY} (d)	7652	2176	NA
E_{MEY} (d)	2660	1849	NA
E_{MEY}/E_{MSY}	0.35	0.85	NA
E_{2023}/E_{MSY}	0.43	0.51	NA
E_{2023}/E_{MEY}	1.25	0.6	NA
Profit (estimated) 2023 ($m) Estimate from these 3 target species based on data provided and assumptions of fixed costs proportion to Tiger Prawn fishery versus Banana Prawn fishery. Revenue from other species (e.g. Red Endeavour Prawns, bugs, squid) not included.		-14.9	

Table Appendix A 2. Sensitivity test outputs for Grooved Tiger Prawns.

EMSY is the effort level (expressed in terms of 2023 boat days) at which MSY is achieved and SMSY is the spawner stock index at which the (deterministic) MSY is achieved.

	Base Case	DDD	Mid-High	Cstrs effort change 200	Cstrs effort change 50	Cstrs effort change No	No effort thrshd	Estimate Pattern	Base Case plus red end.
Steepness	0.43	0.371	0.4	0.43	0.43	0.43	0.43	0.43	0.43
$Catch_{2024}$ (t)	675	1065	677	675	675	675	263	732	676
Observed C_{2023} (t)	921	921	921	921	921	921	921	921	921
MSY (t)	1632	1470	1535	1632	1632	1632	1632	1674	1632
MEY (t)	1109	1118	1105	1109	1109	1109	1109	1152	1122
S_{MSY}	0.251	0.495	0.229	0.251	0.251	0.251	0.251	0.185	0.251
S_{MEY}	0.375	0.665	0.383	0.375	0.375	0.375	0.375	0.397	0.373
S_{MEY}/S_{MSY}	1.496	1.345	1.669	1.496	1.496	1.496	1.496	2.146	1.489
S_{2023}/S_0	0.55	0.5	0.52	0.55	0.55	0.55	0.55	0.55	0.55
S_{2023}/S_{MSY}	1.08	0.91	1.17	1.08	1.08	1.08	1.08	1.47	1.08
S_{2023}/S_{MEY}	0.72	0.68	0.7	0.72	0.72	0.72	0.72	0.68	0.73
5-year mav($S_{2019\text{-}2023}/S_{MSY}$)	1.07	0.91	1.16	1.07	1.07	1.07	1.07	1.45	1.07
S_{2030}/S_{MEY}	0.99	0.96	0.97	0.99	0.99	0.99	1	0.99	0.99
Observed nominal E_{2023} (d)	3314	3314	3314	3314	3314	3314	3314	3314	3314
Estimated nominal E_{2024} (d)	2645	3446	2658	2646	2645	2646	822	2923	2650
Estimated nominal E_{2025} (d)	3036	3513	3026	3037	3036	3037	1644	3188	3041
E_{MSY} (d)	7652	4988	7858	7652	7652	7652	7652	13673	7652
E_{MEY} (d)	2660	2546	2539	2660	2660	2660	2661	2720	2713
E_{MEY}/E_{MSY}	0.35	0.51	0.32	0.35	0.35	0.35	0.35	0.24	0.35
E_{2023}/E_{MSY}	0.43	0.66	0.42	0.43	0.43	0.43	0.43	0.24	0.43
E_{2023}/E_{MEY}	1.25	1.3	1.3	1.25	1.25	1.25	1.25	1.22	1.22
Total loss to that of Base Case[1]	100	46	83	100	100	100	90	51	88

[1]This doesn't apply to the Grooved Tiger Prawns only. It is the sum for all Tiger Prawn fishery fleets and species included in this assessment and based on estimated allocation of fixed costs to the Tiger Prawn fishery (versus the Banana prawn fishery) dependent on the revenue share of each fishery to total. It is in loss, therefore the smaller of the value, the better of economic performance.

Table Appendix A 3. Sensitivity test outputs for Brown Tiger Prawns.

E_{MSY} is the effort level (expressed in terms of 2023 days) at which MSY is achieved and S_{MSY} is the spawner Stock index at which the (deterministic) MSY is achieved.

	Base Case	DDD	Mid-High	Cstrs effort change 200	Cstrs effort change 50	Cstrs effort change No	No effort thrshd	Estimate Pattern	Base Case plus red end.
Steepness	0.311	0.269	0.299	0.311	0.311	0.311	0.311	0.311	0.311
$Catch_{2024}$ (t)	361	192	359	361	361	361	189	377	360
Observed C_{2023} (t)	321	321	321	321	321	321	321	321	321
MSY (t)	982	915	959	982	982	982	982	1109	982
MEY (t)	856	831	876	856	856	856	860	852	865
S_{MSY}	0.234	0.505	0.243	0.234	0.234	0.234	0.234	0.212	0.234
S_{MEY}	0.334	0.654	0.35	0.334	0.334	0.334	0.333	0.306	0.331
S_{MEY}/S_{MSY}	1.425	1.295	1.443	1.425	1.426	1.425	1.421	1.45	1.414
S_{2023}/S_0	0.41	0.37	0.37	0.41	0.41	0.41	0.41	0.41	0.41
S_{2023}/S_{MSY}	0.81	0.7	0.78	0.81	0.81	0.81	0.81	0.90	0.81
S_{2023}/S_{MEY}	0.57	0.54	0.54	0.57	0.57	0.57	0.57	0.62	0.58
5-year mav($S_{2019-2023}/S_{MSY}$)	0.87	0.76	0.83	0.87	0.87	0.87	0.87	0.87	0.87
S_{2030}/S_{MEY}	0.96	0.91	0.91	0.96	0.96	0.96	0.97	1.96	0.96
Observed nominal E_{2023} (d)	1116	1116	1116	1116	1116	1116	1116	1116	1116
Estimated nominal E_{2024} (d)	1368	568	1356	1368	1369	1368	714	1081	1364
Estimated nominal E_{2025} (d)	977	501	988	977	978	977	939	816	973
E_{MSY} (d)	2176	2469	1970	2176	2176	2176	2176	3466	2176
E_{MEY} (d)	1849	1717	1798	1849	1848	1849	1866	1537	1880
E_{MEY}/E_{MSY}	0.85	0.7	0.91	0.85	0.85	0.85	0.86	0.44	0.86
E_{2023}/E_{MSY}	0.51	0.45	0.57	0.51	0.51	0.51	0.51	0.32	0.51
E_{2023}/E_{MEY}	0.6	0.65	0.62	0.6	0.6	0.6	0.6	0.73	0.59

Table Appendix A 4. Sensitivity test outputs for Blue Endeavour Prawns**.**

E_{MSY} is the effort level (expressed in terms of 2023 boat days) at which MSY is achieved and S_{MSY} is the spawner stock index at which the (deterministic) MSY is achieved.

	Base Case	DDD	Mid-High	Cstrs effort change 200	Cstrs effort change 50	Cstrs effort change No	No effort thrshd	Estimate Pattern	Base Case plus red end.
$Catch_{2024}$ (t)	209	238	209	209	209	209	80	208	209
Observed C_{2023} (t)	233	233	233	233	233	233	233	233	233
MSY (t)	435	479	435	435	435	435	435	659	435
MEY (t)	199	478	192	199	199	199	200	189	203
S_{MSY}	7902	0.208	7902	7902	7902	7902	7902	6973	7902
S_{MEY}	7819	0.288	7840	7819	7819	7819	7817	7850	7809
S_{MEY}/S_{MSY}	0.99	1.382	0.992	0.99	0.99	0.99	0.989	1.126	0.988
S_{2023}/S_0	1.01	0.31	1.01	1.01	1.01	1.01	1.01	1.01	1.01
S_{2023}/S_{MSY}	1.17	0.77	1.17	1.17	1.17	1.17	1.17	1.33	1.17
S_{2023}/S_{MEY}	1.18	0.56	1.18	1.18	1.18	1.18	1.18	1.18	1.18
5-year mav($S_{2019-2023}/S_{MSY}$)	0.95	0.82	0.95	0.95	0.95	0.95	0.95	1.07	0.95
S_{2030}/S_{MEY}	1.02	1.01	1.02	1.02	1.02	1.02	1.03	1.02	1.02

Table Appendix A 5. Sensitivity test outputs for Red Endeavour Prawns**.**

E_{MSY} is the effort level (expressed in terms of 2023 boat days) at which MSY is achieved and *S_{MSY}* is the spawner stock index at which the (deterministic) MSY is achieved.

Indicator	Base Case	Base Case plus Red Endeavor
$Catch_{2024}$ (t)	NA	77
Observed C_{2023} (t)	NA	127
MSY (t)	NA	175
MEY (t)	NA	72
S_{MEY}/S_{MSY}	NA	0.88
S_{2023}/S_0	NA	1.01
S_{2023}/S_{MSY}	NA	1.08
S_{2023}/S_{MEY}	NA	1.22
5-year mav($S_{2019-2023}/S_{MSY}$)	NA	1.00
S_{2030}/S_{MEY}	NA	1.04

Appendix B. Estimates of relative fishing power in the NPF Tiger Prawn Fishery

Table Appendix B 1. The NPF Tiger Prawn fishing power series applied in the 2024 assessment.

The Base Case uses the values from the “low” series, while the sensitivity run uses the “mid-high” series.

Year	Relative fishing power (low)	QINC (low)	Relative fishing power (Mid-High)	QINC (Mid-High)
1970	1.00		1.00	
1971	1.29	1.29	1.29	1.29
1972	1.33	1.03	1.34	1.04
1973	1.48	1.11	1.55	1.15
1974	2.27	1.53	2.43	1.57
1975	1.79	0.79	1.93	0.79
1976	2.25	1.26	2.42	1.25
1977	2.20	0.98	2.33	0.96
1978	2.31	1.05	2.45	1.05
1979	2.52	1.09	2.69	1.10
1980	2.68	1.06	2.87	1.06
1981	2.65	0.99	2.84	0.99
1982	2.88	1.09	3.09	1.09
1983	2.97	1.03	3.20	1.04
1984	2.92	0.98	3.15	0.99
1985	3.22	1.10	3.47	1.10
1986	3.40	1.05	3.66	1.05
1987	2.87	0.85	3.11	0.85
1988	2.95	1.03	3.22	1.04
1989	3.12	1.06	3.43	1.06
1990	3.23	1.03	3.59	1.05
1991	3.50	1.08	3.95	1.10
1992	3.45	0.98	3.92	0.99
1993	3.50	1.02	3.98	1.02
1994	3.68	1.05	4.18	1.05
1995	3.72	1.01	4.22	1.01
1996	3.76	1.01	4.27	1.01
1997	3.92	1.04	4.44	1.04
1998	4.16	1.06	4.72	1.06
1999	4.11	0.99	4.67	0.99
2000	4.17	1.01	4.74	1.01
2001	4.21	1.01	4.78	1.01

2002	4.10	0.97	4.65	0.97
2003	4.26	1.04	4.83	1.04
2004	4.07	0.96	4.61	0.96
2005	3.82	0.94	4.33	0.94
2006	3.65	0.96	4.14	0.96
2007	3.52	0.96	4.00	0.96
2008	4.35	1.23	4.93	1.23
2009	4.68	1.08	5.32	1.08
2010	4.66	0.99	5.29	0.99
2011	4.79	1.03	5.43	1.03
2012	4.79	1.00	5.44	1.00
2013	5.14	1.07	5.84	1.07
2014	5.08	0.99	5.77	0.99
2015	5.58	1.10	6.34	1.10
2016	5.70	1.02	6.47	1.02
2017	5.62	0.99	6.38	0.99
2018	5.99	1.07	6.81	1.07
2019	6.34	1.06	7.20	1.06
2020	5.77	0.91	6.55	0.91
2021	6.11	1.06	6.93	1.06
2022	5.82	0.95	6.61	0.95
2023	6.43	1.11	7.30	1.11

Published by CSIRO Oceans and Atmosphere.

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